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ABSTRACT

As an attempt to confirm the view that the relationships between certain classroom process variables and student achievement are curvilinear, first grade reading and mathematics data from the Stallings and Kaskowitz (1974) Project Follow Through Classroom Observation Evaluation were reanalyzed using orthogonal polynomial regression methods. Seventy-five classroom process variables were selected from Stallings and Kaskowitz data and entered into poly-nomial regression analyses. Thirty-two of ninety-five relationships tested were found to be nonlinear. (This, of course, is well beyond chance.) Fourteen of the nonlinear functions were quadratic in nature, eleven were cubic, and seven were quartic. Fifteen of these functions were related to mathematics achievement, and seventeen were related to reading achievement. These results generally support the view that relationships between some classroom process variables and student achievement are probably curvilinear. In turn, this finding seems to raise a question about recommendations for instructional improvement that are made based solely on linear analyses of process-product study data. This finding also provides additional support for the argument to employ both linear and nonlinear analyses in classroom process-product research. (Author/MP)

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IN SEARCH OF NONLINEAR PROCESS-PRODUCT FUNCTIONS IN EXISTING SCHOOLING EFFECTS DATA: I. A REANALYSIS OF THE FIRST GRADE READING AND MATHEMATICS DATA FROM THE STALLINGS AND KASKOWITZ FOLLOW THROUGH STUDY

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Abstract

As a part of a search effort for curvilinear process-product relationships, first grade reading and mathematics data from the Stallings and Kaskowitz (1974) Project Follow Through Classroom Observation Evaluation were reanalyzed using orthogonal polynomial regression methods. Seventy-five classroom process variables were selected and entered into polynomial regression analyses. Thirty-two of ninety-five relationships tested were found to be nonlinear. This, of course, is well beyond chance. Fourteen of the nonlinear functions were quadratic in nature, eleven were cubic, and seven were quartic. Fifteen of these functions were related to mathematics achievement, and seventeen were related to reading achievement. These results generally support the view that relationships between some classroom process variables and student achievement are probably curvilinear. In turn, this finding seems to raise a question about recommendations for instructional improvement that are made based solely on linear analyses of process-product study data. This finding also provides additional support for the argument to employ both linear and nonlinear analyses in classroom process-product research.

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I. INTRODUCTION

Improvement of the delivery of basic skills instruction to students has always been the preeminent goal of educational R&D. But as yet research has not found any innovation of our educational system that consistently relates to outcomes in the traditional basic skills areas of mathematics and reading.

Nevertheless, new understandings regarding the relationship between classroom practices and student achievement, and of the change process itself, provide one with a measure of hope. Medley (1978), for example, has concluded that "where sufficient effort and resources have been applied to the study of teacher effectiveness, useful and dependable findings have emerged" (p. 22). And from the literature on change one learns that there is increasing reason to believe that even the best of innovations will not succeed unless they are the achievement of joint efforts of practitioners and researchers, and are differentially employed by practitioners according to objectively determined needs at the level of intended use.

One prerequisite to the improvement of basic skills instruction seems to be for researchers and practitioners especially--given variations in student characteristics and in the goals of instruction--to understand better how classroom practices can be optimized in order to maximize student achievement in mathematics and reading. In this respect, Luecke and McGinn (1975) have observed:

> For us, advancement will come through an improved understanding of what actually takes place in schools and classrooms. Studies using educational production functions must attend more to variables pertinent to the educational production process. (p. 350)

In the last decade, well-designed and large-scale studies were implemented to examine the instructional process in respect to student outcomes. Medley (1977) has listed fourteen of these process-product studies and there are even more. History is certain to applaud the efforts of all those associated with such research for it is already clear that their work has advanced greatly our understandings of teaching effectiveness. Nevertheless, it is probable that some of the conclusions drawn from the results of those studies exclusively utilizing linear production functions are in need of reexamination for reasons soon to become apparent. Conclusions drawn from production functions which are positive and linear would imply that "more is better" while a negative and linear function would suggest that "less is better." It is not unusual for the linear results of process-product research to be translated into a "tentative" set of recommendations for instructional improvement and then "universally prescribed." Soar and Soar (1976) believe that these types of innovations are limited:

> They are simplistic in implying that if some of a behavior is good, more is better; and once the question is raised, it becomes difficult to imagine very many behaviors for which increasing amounts would be unqualifiedly good. (p. 265)

The Soars continue their argument by indicating:

> Advocates of change in teacher behavior do not often identify limits for the behavior they recommend increasing or decreasing. There may, of course, be a small number of measures for which straightline relationships really are appropriate, such as negative affect. It would not be surprising if increasing amounts of this behavior were increasingly destructive. But it seems doubtful that such relations are typical, as the use of product-moment correlation implies. (p. 265)

It has been advocated that nonlinear analysis should be performed along with linear analysis. Brophy and Evertson (1974), for example, concluded:

> The findings of the present study . . . point to the need for routinely investigating nonlinear as well as linear relationships between teacher behavior and student outcomes. . . . The present study has shown that many relationships which do not appear in correlational analyses are revealed when nonlinear analyses are performed, and, more importantly, that most teacher behaviors are related non-linearly to student outcome measures. (pp. 166-167)

Soar and Soar (1973) reached a similar conclusion:

> The methodological implication of these data appears to be a strong argument for the importance of analyzing classroom data interactions and nonlinear relations, since linear relations apparently represent only a small portion of the meaningful variance in classroom behavior and its relation to pupil gain. (p. 149)

Implicit in the above is the notion that linear production functions should not receive exclusive consideration in teacher effectiveness research; instead, researchers are urged to realize that some relationships more appropriately are described by functions reflecting the law of diminishing marginal productivity. Samuelson, for example, indicates that "some inputs relative to other fixed inputs will, in a given state of technology, cause total output to increase; but after a point the extra output resulting from the same additions of extra inputs is likely to become less and less" (p. 52). The questions of concern here may be: How does student achievement change with increasing inputs of one classroom variable while all other variables remain fixed? And, are there optimal levels of

a particular classroom practice that will tend to maximize student achievement? This latter question leads us directly back to the issue of nonlinearity.

A number of studies have reported nonlinear relations between measures of achievement and direct and/or proxy measures of classroom practices (e.g., Coats, 1966; Brophy & Evertson, 1974; Loucks, 1975; Soar, 1966, 1968, 1971, 1973; Soar & Soar, 1973). Soar and Soar (1976), for example, reported:

> Nonlinear relations were found between measures of achievement gain and measures of teacher behavior which appeared to represent teacher limitation of pupil freedom in the development of subject matter and thought. (p. 263)

Elsewhere, Soar (1966) reported that "intermediate levels of teacher control . . . produced more pupil change in desirable directions than did extreme lack of teacher control" (p. 248).

Of course, such findings as those reported above cannot be ignored by any new effort to assist practitioners to improve their basic skills instruction. Indeed, it would appear that recommendations for instructional improvement based solely on linear relationships may not only be subject to some error but, more importantly, may inadvertently bypass some important process-product relationships.

This secondary analysis effort should not be construed as strictly exploratory; sufficient evidence is now available to suggest that nonlinear functions probably will be found in all large-scale process-product

research (e.g., Soar & Soar, 1973). Nevertheless, this reanalysis does represent an attempt to confirm the view that the relationships between certain classroom process variables and student achievement are curvilinear. Such additional evidence would not only clearly imply the usefulness of designing supervision and inservice training according to individually diagnosed teacher opportunities or needs, but would also provide some of the data that could be used by teachers for diagnosing and prescribing instructional modifications.

It is this latter need that is at the heart of this current reanalysis effort. It is proposed that both linear and curvilinear process-product data should be explored for their potential utility to improve instruction in basic skills. Important relationships could then be translated for teachers in a form they themselves can employ to discover opportunities for self-improvement. A concrete example may be helpful. The Basic Skills Component of the Development Division of Research for Better Schools, Inc., is in the process of field-developing models for assisting practitioners to improve their basic skills instruction. These models assume that practitioners can and should compare their own classroom practices with reference functions (or tables) that relate the classroom practices of others to student outcomes. Practitioners not functioning at levels that insure maximum student achievement for a given combination of students and instructional goals would welcome the opportunity to modify either or both their behavior or classroom conditions. The use of both linear and nonlinear process-product functions derived from large-scale studies is seen as essential to this process.

Selecting Data Sets for Reanalysis

In selecting the Stallings and Kaskowitz (1974) data set for secondary analysis, the following criteria were used:

1. Only data sets from major studies of classroom process-product relationships were to be considered. In other words, each data set was to include classroom process variables and student achievement scores for a relatively large sample of classrooms.

2. Data sets were to be constituted so as to provide for the computation of residual scores. Such data sets were to contain student initial ability and end-of-treatment achievement test scores (or pretest and posttest scores) in the areas of reading and/or mathematics.

3. Linearity of process-product relationships should have been assumed but not actually tested during the primary analysis.

4. The data should have been collected from elementary grade (i.e., K-8) classrooms.

5. Data sets were to be available for purposes of reanalysis.

6. Data sets were to be easy to access.

At least two data sets out of the sixteen major process-product studies identified met criteria 1 through 5. These were the Follow Through Classroom Observation Evaluation, 1972-1973 (Stallings & Kaskowitz, 1974) and the Beginning Teacher Evaluation Study: Phase II, 1973-1974 (McDonald & Elias, 1976). The Follow Through Classroom Observation Evaluation data were available from SRI International (T. Middleton, Follow Through Data Bank Manager), and the Beginning Teacher Evaluation Study, Phase II data, from ETS (F. McDonald, the principal investigator). The Stallings and Kaskowitz data set

was chosen for reanalysis primarily because it became available sooner than the McDonald and Elias (1974) data set.

The Organization of the Paper

This paper is divided into six sections. The second section is designed to provide an historical description of research employing nonlinear methodology. It is essentially an annotated review of such studies, and no serious attempt has been made to analyze or synthesize the methodology or results.

The third section briefly describes the Stallings and Kaskowitz (1974) study; methodology and results are described. The fourth section discusses the data and methodology employed for this reanalysis. The results of the reanalysis are described and discussed in the fifth section. The sixth section summarizes the results.

II. AN HISTORICAL REVIEW OF PROCESS-PRODUCT RESEARCH EMPLOYING NONLINEAR ANALYSIS

In this section, studies involving some form of nonlinear analysis of process-product related data are described. It is hoped that a sense of methodological developments in this area will become apparent, although no attempt has been made to synthesize either the techniques or the results reported herein.

The Review

Perhaps the first researchers to "test" for nonlinear process-product relationships were Solomon, Bezdek, and Rosenberg (1963). They related the behaviors of twenty-four teachers in thirteen adult-learning centers to student achievement and attitudes in an introductory American Government course. Teacher classroom behavior was rated on two occasions in the middle of the term by a team of observers using an instrument containing thirty-eight scales. At the same time, tape recordings were made and later analyzed with respect to the speech of teachers and students with statements being assigned to broad categories, such as "interpretation," "factual," "organizing," "hypothetical," "opinion," and "personal preference"; teacher feedback to students was also analyzed. To complement the observational data, two questionnaires were employed to elicit additional information. A teacher questionnaire was used to obtain self-report data on teaching goals and motives for teaching. Students rated a broad range of teacher behaviors and reported their attitudes toward the instructor.

the course, the amount of learning, and the amount of interest they developed.

The four data-gathering procedures produced together 169 different items referring to the behavior of teachers. These variables were factor analyzed and yielded the following eight factors, which provided the basis for computing factor scores for classroom processes: (1) permissiveness vs. control; (2) lethargy vs. energy; (3) aggressiveness vs. protectiveness; (4) obscurity/vagueness vs. clarity/expressiveness; (5) encouragement of content-related student participation vs. non-encouragement of participation/student growth emphasis; (6) dryness vs. flamboyance; (7) encouragement of students' expressive participation vs. lecturing; and (8) warmth vs. coldness.

The amount of learning acquired by students was measured by administering a multiple-choice achievement test at the beginning and end of the semester. The specially constructed test contained two parts: one part measured factual information, and the other measured comprehension. Residual scores were computed, but because the correlations between the residual scores and unadjusted gain scores were so high, Solomon et al. decided to use the unadjusted gain scores as indicators of schooling effects. Attitudes toward the instructor, the course, the amount of learning achieved, and the interest developed were assessed by use of the student questionnaire. Status attainment scores were used in the analysis of attitudes.

Zero-order correlations were calculated to determine the association between the eight teacher factor scores and student achievement. On the

chance that some of these process-product relationships might prove to be nonlinear, a series of 2 x 3 Chi-square analyses was conducted by dichotomizing student scores into high and low categories based on a median split and trichotemizing teachers into upper, middle, and lower thirds according to their scores on each factor. Sixteen Chi-square analyses were computed for the combination of factor by test complexity (i.e., factual/concrete, comprehension/abstract). In addition, the analysis of variance technique was used to assess context by process interactions.

The Chi-square technique produced only one significant finding that Solomon et al. construed as possibly representing a nonlinear outcome. (Actually, a polynomial regression analysis would be needed to confirm the fact that the actual function is curvilinear, since the Chi-square process could distort the true relationship.) The classroom factor found to be significantly related to gain in comprehension was that of permissiveness vs. control. Other analysis revealed that gains in factual information were related to teacher scores on clarity/expressiveness and lecturing. In the judgment of Solomon et al., these latter two factors "represent behaviors and qualities of behavior which provide the most efficient way for a teacher to present and transmit factual material" (p. 6).

Flanders (1970) indicated that "the main credit for identifying and conceptualizing nonlinear (or curvilinear) relationships belongs to Soar" (p. 403). This review of the literature supports this historical view. In the first of a series of chiefly process-product studies, in

which some form of nonlinear analysis was undertaken, Soar (1966) examined how a set of presage and process variables was related to student outcomes (i.e., products) in grades three through six. The staffs of four elementary schools, consisting of fifty-seven teachers, volunteered for the study. In the fall of the first year, data collection was begun with the administering of achievement, personality, and creativity tests to all pupils; a group test of problem-solving skills was also administered in each classroom. At about the same time, teachers were administered self-report personality tests. During the middle of the school year, classroom observations were conducted using Flanders Interaction Analysis and the South Carolina Observation Record. In the spring of the first and second years, students were readministered the pretest battery as well as attitude measures.

Through the use of analysis of variance, Soar examined the cumulative effect of different sequences of varying levels of classroom conditions over a two-year period. The four classroom process factors that had correlated most clearly with student growth the first year (i.e., "teacher criticism," "extended discourse vs. rapid teacher-pupil interchange," "pupil hostility vs. teacher support and pupil interest," and "indirect teaching vs. silence and confusion") were selected for study over the two years. Teachers were assigned to high, middle, and low categories on each of four process factors for each year. In this type of analysis, one type of curvilinear relationship (i.e., an inverted U shape ∩) would be suggested by greater pupil growth for the middle positions relative to low and high categories. The four

process variables were studied in relation to five student measures: two achievement, two personality, and one dealing with creativity. Student measures of residual true gain for the two separate years were summed in order to yield a total residual true gain for the two years of the project and, thus, served as the indicator of schooling effect for this aspect of the study.

Results of the teacher criticism factor across the achievement and creativity measures seemed to suggest that for these two types of measures high teacher criticism produced the least growth and that moderate amounts of teacher criticism were optimal. The two personality measures produced similar results. Soar interprets such findings as perhaps indicating "that at least a minimum of control of deviant behavior is both necessary and desirable from the pupil point of view. Perhaps the optimum of teacher criticism is more than the least which is represented here" (p. 229). Another finding was that the trends noted above were clearer for the second year than the first. Soar felt that the data suggested "that what went on the year earlier matters less in the amount of growth shown over two years than the more recent influences do" (p. 228).

For the indirect teaching factor in respect to achievement and personality measures, the greatest desirable student change appeared at intermediate values of the factor. This was not the case for the creativity measure, where the optimal level for growth was associated with a lower level of teacher direction than was the optimal level for achievement and personality measures. Soar concluded:

> Intermediate levels of teacher control, expressed either as criticism or as indirect teaching, produced more pupil change in desirable directions than did extreme lack of teacher control. Perhaps the explanation is the need for the teacher to provide a minimum of structure within which pupil growth will be maximized. (1966, p. 248)

In 1966, Coats (as reported in Flanders, 1970) reanalyzed Flanders Interaction Analysis (Flanders, 1965; Flanders et al., 1969) data collected during 1959-1960 and 1964-1965 by Flanders and his associates. Coats uncovered some curvilinear relationships that proved to be statistically significant. As indicators of schooling effects, Coats employed standardized status attainment scores (i.e., achievement and attitude posttest scores) from twenty-nine self-contained classes, fifteen seventh grade English-social studies classes, and sixteen eighth grade mathematics classes. The independent variables consisted of pretest scores on the achievement and attitude measures, a measure of intelligence, and twenty-seven classroom verbal interaction variables. Both regression and variance analyses were used in determining the nature and strength of associations between classroom processes and educational outcomes, with the classroom as the unit of analysis.

Using polynomial regression analysis, Coats found that all significant process-product functions were essentially linear, with the exception of [illegible] that were quadratic and one that was cubic. Statistically significant inverted U-shaped relationships were found between teacher criticism (i.e., restrictiveness, restrictive feedback, and negative authority) and postachievement scores for the sixth and seventh grade samples. The remaining curvilinear relationships Coats

plotted employed pupil postattitude as the dependent variable and sustained acceptance and preattitude scores as the independent variables. The functional relationship between sustained acceptance and postattitudes may be described as a positively decelerating curve (i.e., ⌒). Preattitude was functionally related to postattitude in a shape that may be best described as a positively accelerating (i.e., ⌒) curve.

Although they did not employ any cognitive measures as dependent variables, in 1968 Thompson and Bowers (as reported in Soar, 1972) related classroom process measures to creative growth in fourth grade pupils. One of their findings was that middle-level teacher verbal output (as well as convergent teacher style) was associated with greatest growth in total creativity.

In another study, Soar (1968) argued that "there is an optimal level of teacher indirectness which is less than the maximum possible and an optimal level of teacher criticism which is greater than the minimum possible" (p. 275). With this argument in mind, he asked: "Do all learning tasks have the same optimal levels of teacher behavior?" (p. 275). In an attempt to explore this issue, Soar reanalyzed data from his 1966 study.

Using pupil data from the first year of testing, Soar calculated growth measures for reading, vocabulary, and creativity by estimating true gain and adjusting the remaining relations with initial standing. Factor scores for indirectness of teacher control and for teacher criticism were used along with the residual true gain scores to assess process-product relationships. Soar used a polynomial

regression program to determine the nature of the relationships. Once the relationships were determined--and most of these functions seemed to be nonlinear--Soar tested for differences in optimal levels for the three growth measures that were assumed to vary in complexity in the order in which they were listed above.

The results tended to support Soar's notion that differing optimal levels of indirectness would parallel differences in the abstractness or complexity of the growth measure. However, the results for teacher criticism were not as supportive. Soar concluded:

> Perhaps what these two sets of findings together indicate is that teacher behavior should shift materially in indirectness from concrete to abstract subject matters, but that all teaching should proceed under a relatively supportive emotional climate. (p. 278)

Soar also suggested that effective teachers must be able to shift teaching styles as they shift objectives. He also indicated:

> The possibility suggested by these findings is that families of curves may be identified which would specify the degree of directness which will produce most pupil growth for a given subject matter (or, more likely, for a set of immediate objectives). (1966, p. 279)

In the first of a series of reports (Soar, 1971; Soar & Soar, 1972; Soar, 1973) dealing with the evaluation of Project Follow Through's planned variation experiment, Soar sought both to describe observed differences among sponsored programs in terms of classroom behaviors and to relate those classroom processes to student outcomes. Observations were carried out over a two-year period in a sample of

kindergarten and first grade classrooms selected from each of seven programs and a comparison sample. Pairs of observers spent a winter's day in each of seventy classrooms, each observer using a different instrument (i.e., Teacher Practices Observation Record and Florida Affective Categories--1969, or Florida Climate and Control System--1970) and making an audiotape, which was later coded on two other systems (i.e., Reciprocal Category System and Cognitive Taxonomy). The four systems recorded such things as the teachers' classroom management techniques, expression of affect, and the social-emotional nature and cognitive level of the interaction. In addition to these instruments, observers "globally" rated the classroom climate and objectively described the context. The results from each instrument were factor analyzed and reduced to process factor scores. The factor scores were then tested for differences between programs by the multiple range test and related to student outcomes by grade and year of observation.

The set of pupil achievement measures, administered yearly by Stanford Research Institute (to a portion of the classrooms observed), differed somewhat across the two years in which classroom data were collected. Scores from the various tests were factor analyzed by Soar and reduced to three subscores representing simple-concrete, skill, and complex-abstract achievement. These scores themselves were reduced to regressed gain scores and were used as the indicators of schooling effects. For each grade, classroom means were calculated for the three product measures and were related to all of the factor scores derived from the observational data.

In general, Soar (1971) found highly significant differences in classroom behavior associated with differences in program sponsorship. Subscores representing simple-concrete, skill, and complex-abstract student growth did not relate strongly with each other, but did seem to relate differently to the various dimensions of classroom behavior and to the different programs.

Despite the above, Soar found that the relations of the observational measures to student growth were scattered and often inconsistent. He attributed this failure to the unreliability of the achievement measures used and to the small number of classrooms available for analysis at each grade level. Soar, citing mainly first grade data for the first year of data collection, spoke to the results of tests of linearity. He reported finding a number of nonsignificant but inverted U-shaped functions and suggested that certain process variables may relate to student growth in a nonlinear fashion. He indicated that "this could account for the lack of relation cited above, and for both lowered correlations and inconsistent ones from group to group" (p. iv).

In the third year of his evaluation-research of Project Follow Through, Soar (1973) again sought to describe differences among sponsored programs in terms of classroom behavior and to relate those classroom processes to student outcomes. Observations were carried out in a sample of kindergarten, entering first grade, continuing first grade, and second grade classrooms selected from eight sponsored programs and a comparison sample. As before, pairs of observers spent a full winter's

day in each of 289 classrooms with each member using a different instrument and making an audiotape, which was later coded on two other systems. The four systems, which are the same as described in Soar (1971), recorded such things as the teachers' classroom management techniques, expression of affect, and the social-emotional nature and cognitive level of the interaction. Classroom climate and an objective description of the context were obtained from the use of two other instruments. Soar and his associates also conducted a substudy involving twenty teachers who had been either high or low in the coerciveness of control of pupil behavior the previous year.

For all three substudies the same set of observations was made. The results from each instrument were factor analyzed and reduced to factor scores. These factor scores were used to test for differences between programs by use of the multiple range test. In addition, highly loaded items from the separate analysis of the instruments were factor analyzed, and these eleven factor scores were treated by profile analysis to group teachers with similar profiles. In turn, Soar explored the relation between programs and teacher profiles and between teacher profiles and student outcomes. In another aspect of the study, factor scores were related to student outcomes by grade.

In the major study, highly significant differences in classroom behavior were found to be associated with differences in program sponsorship, as well as differences among grade levels. Soar reports that "of the 39 factors produced from the six instruments, 36 either discriminated between sponsors or between grade levels" (p. xxi). He

concluded that "the measures possess considerable discriminating power, and also that sponsors have been successful in creating very different milieus for learning" (p. xxi).

The set of pupil achievement measures administered by Stanford Research Institute differed somewhat across grade and testing periods. As before, subtests from the various tests were assigned to categories representing simple-concrete, skill, and complex-abstract achievement. A close examination of the data revealed that for some pupils a ceiling effect was apparent, and Soar elected to eliminate such students from the analysis. Unlike the earlier study, regressed gain was calculated separately by socioeconomic status and ethnic group.

Soar reports linear relationships between classroom processes and student outcomes, but allots very little space for discussing nonlinear relationships: "when curves were plotted for the current data, inverted 'U's were found in some cases, but upright 'U's were found at least as frequently" (p. 202). Soar notes that some of the third-year curvilinear findings differed from prior findings. In response to this, he discusses the methodological and sampling differences from study to study and suggests that such differences could possibly account for discrepancies in findings. One should note that, in a review of curvilinear findings across four of his studies (Soar & Soar, 1976), the results of this third-year study were ignored while the earlier results were discussed.

In a study concerned with the relationship between classroom behavior, pupil characteristics, and pupil growth during the school year

and over the summer, Soar and Soar (1973/1975) made the following predictions:

1. Measures which represent teacher control or structuring of the classroom are likely to be related to pupil cognitive growth in nonlinear fashion.

2. The point on the classroom behavior dimension at which maximum pupil growth occurs is hypothesized to shift with the complexity or abstractness of the learning objective, with the maximum growth of more abstract objectives being associated with less teacher control than will be true for more concrete objectives.

3. Personal characteristics of the pupil such as socio-economic status, anxiety, dependency or impulsiveness will influence (interact with) the level of classroom behavior which is optimal for pupil growth in a particular learning task. (p. 10)

Eighty-one fifth grade and twenty-one first grade classrooms were visited during the late fall and winter by pairs of observers who collected data for the same four observation systems and classroom rating measures as were described in Soar (1971). The observational data were factor analyzed and eventually reduced to a set of eleven factor scores: negative control vs. orderly classroom; teacher control, varied interaction; expansive teaching; pupil initiation; free movement and positive affect with little focus; teacher choice of problem; seat work without teacher; unnamed; higher level cognitive activities; teacher extended lecture; and recitation. All students were administered a fall pretest battery, a spring posttest battery, and a second posttest battery the next fall. Fifth graders were administered achievement tests in reading, vocabulary, spelling, and arithmetic concepts; personality tests for

dependence, anxiety, school achievement motivation, locus of control, and impulsivity; a creativity test; measures of attitudes toward self and school; and an IQ measure. The battery administered to first graders consisted of two achievement tests and measures of self-concept and impulsivity. Pupil data were reduced by calculating a regressed gain measure that regressed posttest score on pretest score for subgroups of pupils identified by IQ level, sex, and race for the fifth grade and by SES, sex, and race for the first grade.

Due to legislated changes, the fifth grade school-year and summer process-product substudy involved only fifty-nine classrooms. Classroom process factors and a priori composites were correlated with student outcomes. The factor scores were then used in stepwise multiple regression to explore interactions and nonlinear relations. Significant nonlinear results were tested separately and plotted by polynomial regression analysis. If the plot suggested an upright or inverted U, the significance of deviation from linearity was tested. Parallel procedures were used to study school-year and summer growth for the first grade sample.

Results for the fifth grade school-year substudy revealed that approximately equal numbers of significant zero-order relations were found for cognitive and noncognitive variables, and "the nonlinear and interaction analyses accounted for relatively larger numbers of significant relationships than the linear analyses did (a ratio of 1.5 to 4)" (p. 143).

Recitation did not relate linearly to the criterion measures but did relate in a strongly nonlinear fashion to several measures of achievement and self-concept. An examination of the curves revealed that intermediate values of recitation were functional, but either too little or too much was not. Soar and Soar indicated that there was limited support for the "differentiated U hypothesis," the second of their predictions. In summarizing their results Soar and Soar stated:

> The integrating thread, and an implication for teaching, appears to be the conclusion that there is an optimum level of structure and control in the classroom, whether by an intermediate value of one behavior or a combination of a behavior that structures and a behavior that does not, which has desirable outcomes for pupils, both cognitive and noncognitive. (p. 143)

Results for the summer substudy indicated that the number of linear relations did not exceed chance expectancy, but that nonlinear and interactive relations were more than four times the amount expected by chance. Pupil initiation was nonlinearly related to student growth over the summer.

Results for the first grade substudy showed that achievement gain was related to moderate amounts of task focus in a positive climate and to a proper match between task difficulty and pupil ability. Self-concept growth was related to intermediate amounts of gentle control in a positive climate. Over the summer, self-concept was related to

intermediate levels of gentle control. In reflecting on their results Soar and Soar suggested:

> The methodological implication of these data appears to be a strong argument for the importance of analyzing classroom data interactions and nonlinear relations, since linear relations apparently represent only a small portion of the meaningful variance in classroom behavior and its relation to pupil gain. (p. 149)

Soar and Soar (1976) reviewed four of their studies (Soar 1966, 1968; Soar & Soar, 1972; Soar & Soar, 1973) in an attempt to identify consistent measures of teacher effectiveness. They reported that in all four studies nonlinear, inverted U-shaped relations appear "to represent teacher limitation of pupil freedom in the development of subject matter and thought" (p. 263). In three studies differentiated U-shaped relations were found, indicating that "different kinds of pupil learning varied in the amount of teacher structuring and limit setting which was associated with greatest pupil gain" (p. 261). In discussing these findings Soar and Soar argued:

> Although linear relationships have most often been used in studies of teaching effectiveness to identify relationships between classroom behavior and pupil gain, it seems clear that they are limited in the extent to which they can help us answer the question of what good teaching is. They are simplistic in implying that if some of a behavior is good, more is better and once the question is raised, it becomes difficult to imagine very many behaviors for which increasing amounts would be unqualifiedly good. (p. 265)

A related issue is that of "universal prescriptions" for increasing teacher effectiveness, which the Soars believe is of questionable use.

In the studies thus far reviewed, it is perhaps safe to say that the sheer number of nonlinear process-product functions reported has not necessarily been overwhelming, considering all of the classroom behaviors that were examined. In part, it is the result of methodological choices--for example, as when Soar (1968, 1971, 1973) only reports quadratic functions having clear inverted or upright U shapes, or when he reduces large batteries of outcome measures to only three levels of cognitive complexity, or when large quantities of classroom data are reduced by him into factor scores. From prior research one comes away with the impression that there are a few highly consistent nonlinear findings.

This impression, however, changes dramatically when the nonlinear data reported by Brophy and Evertson (1974b) for the Texas Teacher Effectiveness Project are examined closely. In their report of the reanalyses of presage-process-product data previously analyzed in terms of zero-order correlations (Brophy & Evertson, 1974a), Brophy and Evertson (1974b) present some 15,000 functions or coefficients. Of these, so many are clearly nonlinear that it is not easy to come away from the data without a strong belief in the need to employ nonlinear analysis in process-product research.

The Texas Teacher Effectiveness Project was a two-year, replicated, naturalistic-correlational study of the relationships between presage

and process variables and student growth in the second and third grades. Only those teachers whose "teacher effectiveness" was stable over a three-year period were observed. Thirty-one teachers were included in the first year of the study and twenty-eight in the second. Four observations by observer pairs were made the first year and fourteen the second year. Both low and high inference measures were used to assess teacher behavior: the Brophy-Good Dyadic Interaction Observation System, Emmer and Peck High Inference Rating Scale, High Inference Coder Checklist Variables, Time Utilization Measures, High Inference Coder Ratings of Teacher Characteristics, Coder Ratings of Lesson Presentation Variables, Low Inference Process Variables, etc. Five subtests from the Metropolitan Achievement Test (MAT) served as criterion measures; residual gain scores were used as the indicator of schooling effects.

The data were presented, where appropriate, in terms of year of study, SES, and MAT subtest. It is not possible here to summarize even a fraction of Brophy and Evertson's findings; however, it is meaningful to review their conclusions regarding nonlinear analysis:

> The findings of the present study . . . point to the need for routinely investigating nonlinear as well as linear relationships between teacher behavior and student outcomes. . . . The present study has shown that many relationships which do not appear in corelational analyses are revealed when nonlinear analyses are performed, and, more importantly, that <u>most</u> teacher behaviors are related nonlinearly to student outcome measures. (pp. 166-167).

Among the more recent studies using nonlinear analysis is the NIE funded study of Calkins, Godbout, Poynor, and Kugle (1976). Calkins and

his associates explored methodological issues and problems relevant to teacher behavior research. These researchers interested themselves primarily in examining relationships between variability of teacher behavior (i.e., the variance of the distribution of values of observed teacher behavior) and student achievement as measured by a series of mathematical subtests. More specifically, it was the intent of the study "to investigate the linear and quadratic contribution of the mean and the variance of the distribution . . . as predictors of student achievement" (p. 3).

Process data were collected in thirty-two high-SES fifth grade classrooms by use of the Global Rating Scales (GRS) and the Teacher Practices Observation Record (TPOR)--high and low inference instruments, respectively. Observation data were obtained during the spring semester in three sessions of math instruction. These data were processed by obtaining a mean and a variance for each scale for each teacher by collapsing the data across the three observation periods.

Student achievement data were collected on project-designed instruments during fall and spring instructional periods. The mathematics test consisted of a total of thirty-three multiple-choice items designed to assess six content areas. A multiple regression technique with pretest performance being entered first was used to obtain correlation data.

In a discussion of their results, Calkins et al. indicated: "Since

the number of statistically significant relationships is so low, it is probably unwise to interpret these results as evidence of 'real' relationships, as they could conceivably all be Type I errors" (p. 16). An examination of results reveals that, for the mean as a statistic, only 1 out of 77 quadratic analyses of GSR data was significant at the .05 level of confidence, and only 12 of 434 quadratic tests involving the TPOR data reached significance. For the variance as a statistic, the results respectively were: 2 out of 77 and 12 out of 434.

Because of the above findings, Calkins et al. did not attempt to interpret their results. But it is of some interest to note that fifteen of the twenty unique TPOR items that Calkins et al. found to be significantly linearly related to outcomes were also the same TPOR factors that Soar (1973) found to be usually significantly related to "skill" learning; ten of the eleven nonlinear relationships were similarly related to "skill" learning as defined by Soar. Since one could interpret the mathematics tests used by Calkins et al. essentially to be tests of skill, it would appear that their results are not without some support from prior research. In effect, there appears to be some measure of consistency between the findings of Calkins et al. and those of Soar (1973), which suggests that the results of Calkins et al. should not be regarded as due simply to chance. Of course, even this observation must be tempered by the exploratory nature of this latter analysis.

Tests of linearity have also been used to assess the nature of process-product relationships when classroom observations were not employed and teacher self-reports were the only source of data (Loucks, 1975). In this instance, self-report data serve as proxies for data collected by use of direct observation. Loucks (as reported in Hall & Loucks, 1977), in exploring the relationship of "Level of Use" (i.e., the level or stage at which an innovation or treatment is being implemented) to schooling effects (i.e., achievement in mathematics and reading), reanalyzed data collected by Watkins and Holley (1975) concerned with teacher self-reports on issues related to individualization of instruction in the classroom.

In the original study, a total of 134 second and fourth grade teachers in twenty-two schools were interviewed in respect to Level of Use of certain concepts related to individualization. Teachers in eleven of the schools that had officialiy implemented Individually Guided Education (IGE) were assigned to the IGE group; the remaining teachers were assigned to the non-IGE group. Based on interview data, teachers were classified as to one of eight possible Levels of Use categories: (1) nonuse, (2) orientation, (3) preparation, (4) mechanical use, (5) routine use, (6) refinement, (7) integration, and (8) renewal (Hall & Loucks, 1977). Loucks (1975) reports that conventional comparisons of achievement between the IGE and non-IGE groups, using one-way analysis of variance, did not result in any significant differences between groups regardless of subject area or grade level.

A reanalysis of the data on the basis of user and nonuser categories resulted in an altogether different set of outcomes. For example,

> For the second-grade sample, results of analysis of variance indicated that all users of individualized reading showed significantly greater achievement than all nonusers; there were no statistically significant achievement differences between users and nonusers of individualized mathematics. (Hall & Loucks, 1977)

By breaking the Levels of Use dimension into more discrete categories, "the question of whether the pupils of teachers at some Levels of Use have greater achievement than those at other levels was explored" (Hall & Loucks, 1977). Loucks (1975) used a test of linearity on the second grade sample using raw status attainment scores (i.e., postachievement scores in mathematics and reading). The analysis indicated that second-order curvilinear relationships (i.e., quadratic) provided the best fit for teacher Level of Use of individualized instruction and student achievement.

The relationships between Level of Use and achievement in mathematics and reading differed, however. The curve for mathematics is best described as J-shaped; that is, the mathematics achievement scores gradually increase from some midpoint in Level of Use. The curve for reading is best described as inverted U-shaped; that is, reading achievement increases gradually until it peaks at about the midpoint in Levels of Use and then decreases gradually. (It should be noted that it is possible that the reported analyses of variance results are in error, or less likely, that the curves are mistitled. We were unable to confirm this suspicion at the time of this writing.)

Summary

Solomon, Bezdek, and Rosenberg (1963) were perhaps the first to explore the issue of nonlinearity in process-product research. They found that in adult learning centers an intermediate level of "permissiveness" produced higher levels of achievement gain than did either extreme. Soar (1966), who must be given credit for bringing nonlinear analysis methodology into the mainstream of process-product research, found a "differentiated" nonlinear relationship between classroom processes and various student outcomes differing in complexity. More specifically, he found that different amounts of teacher control appear to be optimal for growth in tasks differing in complexity. Higher levels of teacher control are needed for optimal growth in relatively concrete tasks than are optimal for more skill-related tasks, and a still lower level of control is optimal for growth in creativity.

In 1966, Coats presented analyses showing nonlinear relationships. Thompson and Bowers (1968) also reported nonlinear results, but for creative outcomes. In a reanalysis of his 1966 data, Soar (1968) again found indications of nonlinear relations. Then in a series of studies dealing with Project Follow Through programs (Soar, 1971, Soar & Soar, 1972; Soar, 1973), more nonlinear results were reported. These findings were supported by the results of the Soar & Soar (1973) study of school-year and summer student growth.

The Brophy and Evertson (1974b) study is perhaps unique for the sheer number of nonlinear results reported. Their results contain a compelling number of nonlinear functions.

Among the more recent studies using nonlinear analysis is that of the NIE-funded Calkins, Godbout, Poynor, and Kugle (1976) study, which explored methodological issues related to teacher effectiveness, as well as that of Loucks (1975), which used proxy process data to study "Level of Use."

It should be clear from the foregoing that researchers have become increasingly sophisticated in the use of nonlinear methodology. For example, Chi-square and analysis of variance techniques were used in early studies to infer curvilinearity; nowadays, polynomial regression analysis is employed instead. It is also interesting to note that many of the studies reported above represent secondary analyses of data collected earlier, often by other investigators.

III. THE STALLINGS AND KASKOWITZ STUDY

In their report, Stallings and Kaskowitz (1974) addressed two questions of educational importance: (1) Has a variety of important educational programs (Planned Variation) been implemented in diverse sites across the country? and (2) If these educational models have been installed, how have they affected the growth and development of children? Included in the study were seven models representing a wide range of innovative educational theories: two behavioristic models (the University of Kansas and the University of Oregon), a model based on the Piagetian theory (High/Scope), a model based on the open education theory (Education Development Center), and three other models, each having its own particular combination of theory and practice drawn from Piaget, Dewey, and the English Infant Schools (Far West Laboratory, University of Arizona, and Bank Street). Approximately twenty first grade and twenty third grade classrooms for each of seven Follow Through sponsors at five or more sites per sponsor were sampled for the study. Since the classroom implementation of Follow Through programs was to be evaluated in terms of the significance of differences between each Follow Through sponsor's classrooms and the non-Follow Through classrooms, thirty-five first grade and thirty-six third grade non-Follow Through classrooms were also included in the study.

The Follow Through Classroom Observation Instrument and other procedures were used in collecting observation data that provided the basis for assessing: (1) the extent of implementation of the sponsor's

models, (2) the relative exportability of the models, and (3) the relationship of classroom process and child outcomes. The Classroom Observation Instrument contains three major sections: (1) the Classroom Summary Information (CSI)section, (2) the Physical Environment Information (PEI) section, and (3) Classroom Observation Procedure (COP), which consists of three parts--the Classroom Check List (CCL), Five-Minute Observation Preamble (PRE), and Five-Minute Observation (FMO). Trained observers collected data on three separate occasions for a full day each time. The first two days were devoted to activity/adult-focused observations and the third day was used for child-focused observations. The CSI and PEI were completed once and the remaining schedules were completed four times an hour.

Classroom Implementation

Program implementation in the classroom was judged on the basis of two criteria: (1) the extent to which sponsor's classroom were found to be uniform on selected implementation variables, and (2) the extent to which a sponsor's classroom differed from the traditional non-Follow Through classrooms in the same variable. Stallings and Kaskowitz developed a list of variables that were descriptive of each sponsor's model, and associated the variables with specific items in their systems. A pool of non-Follow Through classrooms was used in establishing standards via a nonparametric scaling technique. For each sponsor's classroom, an implementation score was computed for each of the sponsor's variables by referring to the standards established on the basis of non-Follow Through classroom data. These scores were then

used for further analyses.

Stallings and Kaskowitz found that the great majority of teachers were conforming to sponsor specifications in implementing programs. In addition, the sponsored programs could be distinguished from each other along important classroom practice dimensions.

Instructional Processes and Child Outcomes

Using 108 first grade and 58 third grade Follow Through and non-Follow Through classrooms for which baseline test data on the Wide Range Achievement Test (WRAT) were available, partial correlations between classroom means on instructional processes and scores on the Metropolitan Achievement Test (MAT) were computed holding WRAT scores constant.

Stallings and Kaskowitz reported that high reading and math scores were associated with more-structured, teacher-initiated classrooms (in both first and third grades), small group instruction (for first grade), large group instruction (for third grade), positive corrective feedback, and the time children spent on reading or math activity.

Stepwise regression analyses were performed to assess the amount of variance accounted for by process variables, beyond that which was accounted for by the WRAT, by entering the WRAT score first in the regression equation. The WRAT score explained 17 to 50 percent of the variances of the MAT first and third grade mathematics and reading scores. A set of ten process variables in the first grade and eight in the third grade accounted for an additional 43 to 64 percent of the mathematic score variances in the first and third grades respectively.

Eight process variables accounted for an additional 23 percent of the reading variance in the first grade, and seven process variables for 37 percent in the third grade.

Based on those findings, Stallings and Kaskowitz concluded their study thus:

> The Follow Through program of planned variation is being implemented, and . . . the seven sponsored models considered in this report are each working to the advantage of children--not by chance but by careful design. (p. 346)

IV. METHODOLOGY FOR THE REANALYSIS

Technical aspects of the current secondary analysis of the Stallings and Kaskowitz (1974) first grade data are described in this section. First, the data set is described, and second, methodology and procedures used for the data reanalysis are outlined.

Data

It was orginally intended that this reanalysis would only deal with a subset of the Stallings and Kaskowitz data. Data either from the first or third grade were to be analyzed only for a limited set of the classroom variables. Further limitations were caused by data inaccessibility, time, and budgetary constraints. For example, it was the authors' intent to utilize individual student data to calculate residual scores for some part of the reanalysis. As it turned out, the author's initial plans were changed because student data were not readily accessible and were too costly given budgetary limits. One other consequence of not obtaining individual student data was the inability to relate selected classroom variables to measures differing in complexity within an achievement area; the scores readily available from SRI International were only for total mathematics, total reading, and word analysis.

Data tapes at SRI International were in binary mode and thus suitable for a CDC 6400 system but not for the IBM/370 system employed by RBS. It became necessary to convert the Stallings and Kaskowitz

Residualizing MAT Mean Scores on WRAT Mean Scores

One way of statistically controlling for unequal initial ability is to employ residualized scores (e.g., Bereiter, 1963; McDonald & Elias, 1974). In an analysis of Project Follow Through, Soar (1973) employed residualized scores; but to deal with the problems of group differences, he calculated separate residualized scores for subgroups. However, due to the lack of accessibility of data at the individual student level, subgroup residualized scores could not be computed for this reanalysis. Residualized scores were computed by regressing MAT class means on WRAT class means. This latter approach enabled the results of this reanalysis to be compared with the results from the Stallings and Kaskowitz primary analysis.

Statistical Analysis

In keeping with the Stallings and Kaskowitz study, the reanalysis was performed on the basis of data from the 108 classrooms that had both WRAT and MAT scores and an attrition rate of less than 80 percent. The following set of steps was employed for the reanalysis:

Step 1. Classroom mean scores on MAT Reading and MAT Mathematics were regressed on WRAT mean scores, and residual mean scores were obtained.

Step 2. Residual mean scores were matched and merged with classroom process variables, and each classroom process variable-residual-mean-score pair was plotted (with a missing data option), using the SPSS Scattergram Analysis program (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975). Zero-order correlations were produced as a by-product of this program.

data from the binary mode to a "character" mode to make it compatible with RBS's systems. The time and costs involved in this activity also led to a number of trade-offs from original intentions: fewer variables were selected for reanalysis and all word analysis data were excluded from the study.

A total of seventy-five variables, selected from the Stallings and Kaskowitz data, were converted into a "character" mode and reanalyzed. These variables were selected on the basis of their compatibility with RBS's intentions to assist states to improve basic skills instruction. The selected variables are listed on Tables 1 through 11; the identifying numbers included there are those used by Stallings and Kaskowitz in their report. Only total mathematics and total reading scores were employed as criterion measures for this reanalysis.

Data from 108 first grade classrooms out of the original set of 171 (for which observation data were available) were retrieved for reanalysis using the same selection criteria Stallings and Kaskowitz used: (1) both the WRAT and MAT had to have been administered to the class, and (2) the attrition rate from fall to spring testing must have been less than 80 percent. Data meeting these requirements were analyzed according to the procedures described below.

Methodology and Procedures

This section describes the methodology involved in computing residualized scores and the steps involved in the statistical analysis.

Step 3. Each scatterplot was examined for the appearance of non-linear relationships.

Step 4. Upon inspection, fifty-three of the original seventy-five variables seemed to be possibly nonlinearly related to either reading residual mean scores or mathematics residual scores and therefore were entered into the polynomial regression analysis. The BMDP5R program (Dixon, 1975) was used because it gives a summary table of goodness-of-fit statistics and scatterplots of observed and predicated values in respect to the independent variable (process variable).

At first, each process variable (X_i) was raised to the fourth power term (X_i^4) and entered into the regression analysis. The form of the regression equation was:

$$Y_i = B_0 + B_1X_i + B_2X_i^2 + B_3X_i^3 + B_4X_i^4 + e_i$$

Step 5. A summary table of goodness-of-fit statistics for each fitted polynomial was reviewed, and those process-residual mean score pairs that showed the best fit at the second or third degree were reanalyzed to the degree of the best fit (see Kerlinger & Pedhazur, 1973, p. 213). The square of the multiple correlation (R^2) and the multiple correlation at the best fit degree were computed from the summary table. The best fit polynomial function was traced on each of the scattergrams.

Step 6. Since zero-order correlations between residual mean scores and process variables are known to be equivalent to partial correlations between posttest mean scores and process variables using the pretest mean scores as a covariate (Linn & Slinde, 1977), it follows that the zero-order correlations obtained for this reanalysis should be equivalent to Stallings and Kaskowitz's partial correlations. A comparison of the correlations from the two analyses was made in order to check the accuracy of the analysis. The results of this comparison reveal that in only four of the instances in which data were available for comparative purposes was there a discrepancy greater than .02 (an acceptable level of divergence, given rounding errors). Perhaps the remaining differences are due to the use in this reanalysis of a missing data option.

V. RESULTS OF THE REANALYSIS AND DISCUSSION

In Section V, the results of the polynomial regression reanalysis of selected variables from the first grade subset of Stallings and Kaskowitz's 108-classroom data set are presented. In order to discuss the results in a meaningful way, the selected classroom process variables are grouped according to the categories (or constructs) developed by Ruff (1978). Thus, the discussion of the reanalyses and the accompanying tables is organized under the following constructs: time, instructional organization, monitoring, management, teacher questioning, teacher reactions to pupil response, pupil response patterns, teaching activities, structure/control, feedback, and qualities of environment. Under each construct, the results are generally presented in the order: construct description, listing of included variables, presentation of analysis results, interpretation of the results, and discussion. Since reviews by Rosenshine (1966, 1967) and by Berliner and Rosenshine (1977) make a number of statements relative to the Stallings and Kaskowitz results, those three reviews are frequently cited in the discussion of the findings.

Understanding the Tables

Each of the following tables, designed to summarize the reanalysis results for one of the constructs listed above, contains the following data: (1) a description of the process variable, (2) correlational data relating process variables to mathematics achievement, and (3) correla-

tional data relating process variables to reading achievement. In the "process variables" columns, variable names and identifying numbers (which are the same as those found in the Stallings and Kaskowitz report) are presented along with the mean, the standard deviation, and the range for the listed process variable. The subscripts "a" and "c" attached to some of the identifying numbers represent either an adult- or child-focus relative to classroom observations.

Presented in columns headed "r" are correlation coefficients representing the association between process variables and mathematics or reading residual scores. A coefficient of $\pm$ .19 or larger is significant at the $p < .05$ level. A single coefficient indicates that the zero-order correlation computed in the reanalysis was identical to Stallings and Kaskowitz's partial correlation coefficient. If two coefficients are listed, they are in the form "secondary analysis result/primary analysis result," and indicate a discrepancy between the results of the primary and secondary analyses. If a relationship was found to be nonlinear, the highest power term entered in the best-fitting regression equation is noted in the column headed "Degree"; the symbols x, x^2, x^3, and x^4 represent linear, quadratic, cubic, and quartic equations, respectively. The shapes of curvilinear functions, reproduced from computer-generated scatterplots through xerography, are also illustrated in the tables. Multiple regression correlation coefficients that are significant at the $p < .05$ level are presented in "R" columns. The computer scattergram plots are themselves provided for in figures located either throughout the body of this

section or in the Appendix. Linear functions are not illustrated on the chart; their slope can be determined, however, from the "r" coefficient.

Time

It is widely acknowledged that time is one of the more important factors influencing student achievement in reading and mathematics. For example, time is the central element of Carroll's (1963) schooling model and of the Wiley and Harnischfeger (1974) model. In the Cooley and Lohnes (1976) model, time is the major component of their "opportunity" construct.

Recently, many researchers have begun to distinguish between the absolute time spent in school (which is calculated from such indices as average daily attendance, length of school day, and length of school year) and the use of time in the classroom (Berliner & Rosenshine, 1977; Gow, 1977; Medley, 1978; Rosenshine, 1976, 1977). Two of the Stallings and Kaskowitz variables that were reanalyzed fall under the "time" construct. These are the percent of the school day the child spent on task-related mathematics or reading activities, that is, "percent of child time spent in numbers, math, arithmetic (66)" and "percent of child time spent in reading, alphabet, language development (67)."

Table 1 indicates that the percent of child time spent in mathematics activities has a curvilinear relationship with mathematics residual mean scores, but that the percent of child time spent in reading activities has a high positive linear relationship with reading residual

Table 1

Summary of Process-Product Relationships: Time

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
66	Percent of "child time" spent on numbers, math, arithmetic activities	16.43	8.06	0.0 - 57.9	.28/.29	.37	x^2	⌒	.19	.41	x^4	∿
67	Percent of "child time" spent on reading, alphabet, language development activities	44.72	15.40	13.07 - 76.65	.18		x		.40		x	

*All "r" coefficients of ± .19 or above are significant at the $p < .05$ level. All "R" coefficients are significant at the $p < .05$ level.

mean scores. Figure 1 appears to indicate that as the percent of time spent in mathematics-type activities increases, so does mathematics achievement, until a peak is reached when about 30 percent of the school day is devoted to such activities; thereafter, students' math achievement decreases as the percent of time spent on mathematics-related activities increases. The optimum amount of time for first grade children's work on mathematics-related activities seems to be about 18-30 percent of a school day; more time than this appears to have diminishing marginal utility.

Reading achievement findings agree with earlier results and support the conclusion of the primary analysis; that is, "children who performed well on tests of reading . . . seemed to be in classrooms where more time was spent in developing academic skills" (Stallings and Kaskowitz, 1974, p. 300). It also is in agreement with both Rosenshine's (1976) statement, "the stronger the academic emphasis, the stronger the academic results" (p. 345), and with findings that greater amounts of instructional reading time were beneficial for low-SES children (Guthrie, in press).

On the other hand, the curvilinear relationship found to exist between time spent on mathematics-related activities and mathematics achievement seems to be more in keeping with the research findings of the Soars (Soar, 1975, Soar & Soar, 1976), rather than with the Rosenshine and Stallings and Kaskowitz statements reported above. The Soars

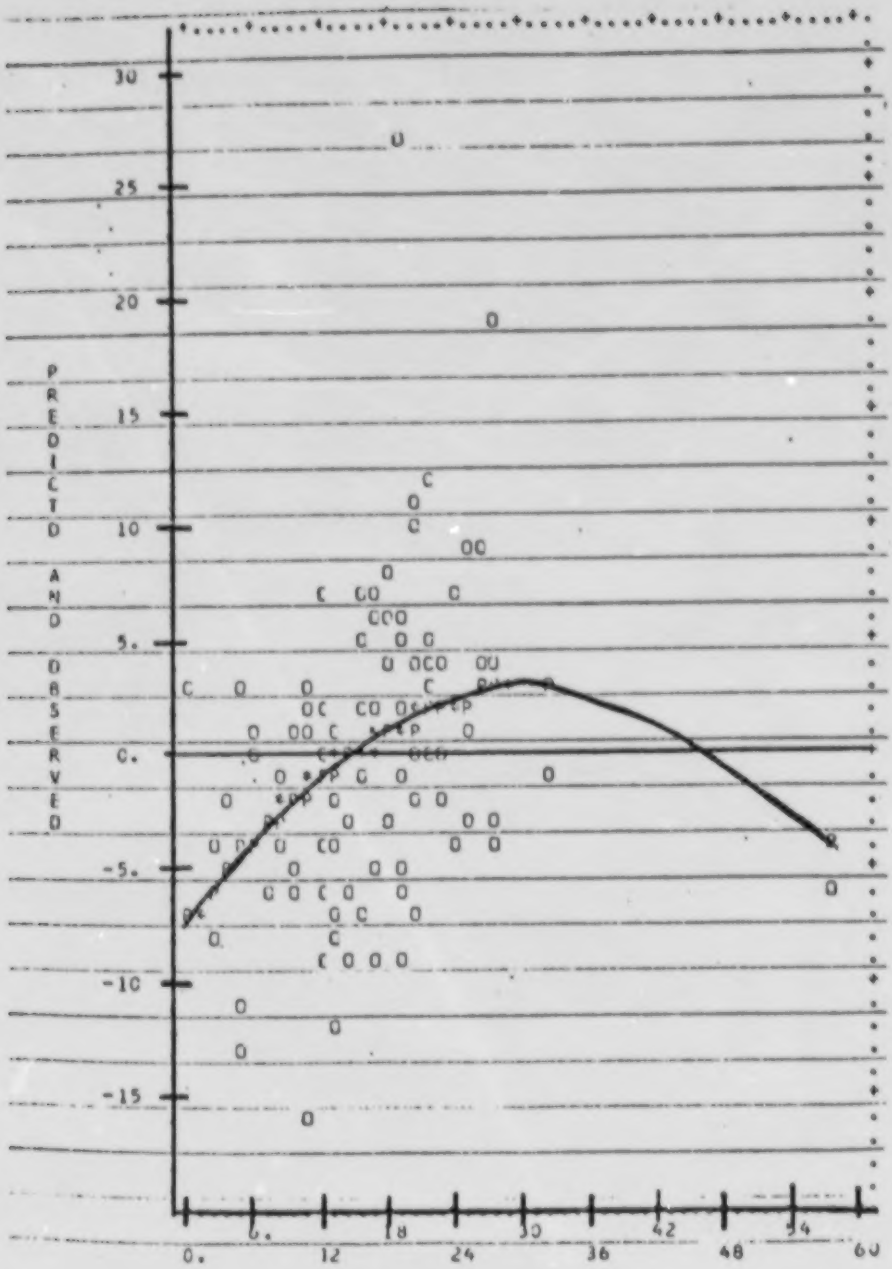

Figure 1. The process-product function for "percent of child time spent on numbers, math, arithmetic" (M/66).

suggest that increasing the amount of time spent on academic activities beyond a certain point may produce only marginal returns. The quadratic curvilinear relationship between mathematics achievement and time spent on mathematics-related activities seems to go beyond Soars' interpretation. However, it should be noted that the function, which is categorized here as an inverted U shape, appears to result from data from one outlier classroom. If this outlier classroom is disregarded, the resulting function undoubtedly would be linear. This suggests that the inverted U function reported here needs to be confirmed by additional data.

Instructional Organization

Ruff (1978) used "instructional organization" to refer to the way teachers group students for instruction. In this study, Stallings and Kaskowitz identified four basic grouping patterns: one child, two children, small group (three to eight children), and large group (nine or more children). Seven of the fourteen process variables assigned to this category are from Stallings and Kaskowitz's original set of variables; the remaining seven have been newly aggregated for this reanalysis.[1] The original variables are the first seven listed in Table 2. Newly aggregated variables are listed in the next half of the Table and have the

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[1] Due to budgetary and time constraints, the authors determined that they could not reanalyze separately all of the Stallings and Kaskowitz variables associated with this category. As an alternative, they elected to establish indices by combining dimensionally related items; e.g., variables 86 (Teacher with one child), 87 (Teacher with two children), 88 (Teacher with small group), and 89 (Teacher with large group) were combined into one index called "Classroom groupings: teacher-individual child interaction time."

Table 2

Summary of Process-Product Relationships: Instructional Organization

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
15	Child/Teacher and Aide Ratio	11.06	5.30	4.11 - 29.00	.08/.09		x		.11	.29	x^3	
109	One child with any adult	1.44	1.58	0.0 - 6.37	-.20	.39	x^2		-.33		x	
140	Total weight in math groupings	215.86	130.76	0.0 - 891.67	.35	.47	x^2		.22	.35	x^3	
142	All children without adults in math	28.59	26.07	0.0 - 84.78	-.10		x		-.20		x	
163	Total weight in reading groupings	574.44	268.15	1.75 - 13.00	.31/ §		x		.40/ §		x	
164	Personalized instruction without adults in reading	3.82	4.49	0.0 - 22.00	-.22		x		-.36/ §		x	
165	All children without adults in reading	7.73	77.00	0.0 - 80.00	-.01	.36	x^4		-.08/ §	.34	x^3	
V1	Classroom groupings: Percent of teacher-individual child interaction time	23.75	11.47	5.61 - 61.25	-.30/ω		x		-.32/ω	.40	x^3	
V2	Classroom groupings: Percent of adult-individual child interation time	23.52	9.98	7.26 - 52.67	-.22/ω	.34	x^2		-.26/ω		x	

Table 2 (cont.)

Summary of Process-Product Relationships: Instructional Organization

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
V3	Classroom groupings: Percent of child-any adult interaction time	12.14	3.30	7.13 - 21.90	.13/ω		x		.07/ ω		x	
V5	Math groupings: Percent of teacher-individual child interaction time	5.38	4.46	0.0 - 20.35	-.06/ω	.22	x^3	~	-.06/ ω		x	
V6	Math groupings: Percent of child-any adult interaction time	13.40	5.33	0.0 - 25.00	-.05/ω		x		-.12/ ω		x	
V7	Reading groupings: Percent of teacher-individual child interaction time	7.16	2.50	1.25 - 14.59	-.18/ω	.26	x^4	~	-.19/ ω	.29	x^4	~
V8	Reading groupings: Percent of child-any adult interaction time	13.14	4.35	4.11 - 22.50	.04/ω	.16	x^4	~	-.06/ω		x	

*All "r" coefficients of ± .19 or above are significant at the p < .15 level. All "R" coefficients are significant at the p < .05 level.

ω: This variable is a new composite and was not studied as such in the primary analysis.

§: Stallings and Kaskowitz did not report these partial correlation coefficients.

prefix "V" attached to their code listing. The first three aggregates (V1, V2, and V3) are related to classroom groupings for all-day activities, the next two (V5 and V6) are related to math groupings, and the last two (V7 and V8) are related to reading groupings. An arbitrary weighting system was used in aggregating variables: the sum of (percent of the time an adult was with one child), one-half of (percent of the time an adult was with two children), one-fifth of(percent of time an adult was with a small group), and one-ninth of(percent of time an adult was with a large group). The results of the reanalysis of these fourteen variables are summarized in Table 2. It should be noted that this secondary analysis was not overly concerned with a close examination of the relationship between mathematics-related process variables (i.e. mathematics groupings) and reading achievement, nor with the relationship between reading-related process variables (i.e., reading groupings) and mathematics achievement. Attention instead was focused on an examination of the relationship between content-related process variables and achievement in that content area.

Seven out of the nineteen relationships between instructional organization variables and student achievement upon which the reanalysis was primarily focused revealed best-fit functions that were curvilinear. Both percent of time one child was with any adult (var. 109) (see Figure 2) and the weighted percent of time adults spent with children (var. V2) (see Figure 3) were found to have upright U-shaped curvilinear relationships with mathematics achievement. This indicates

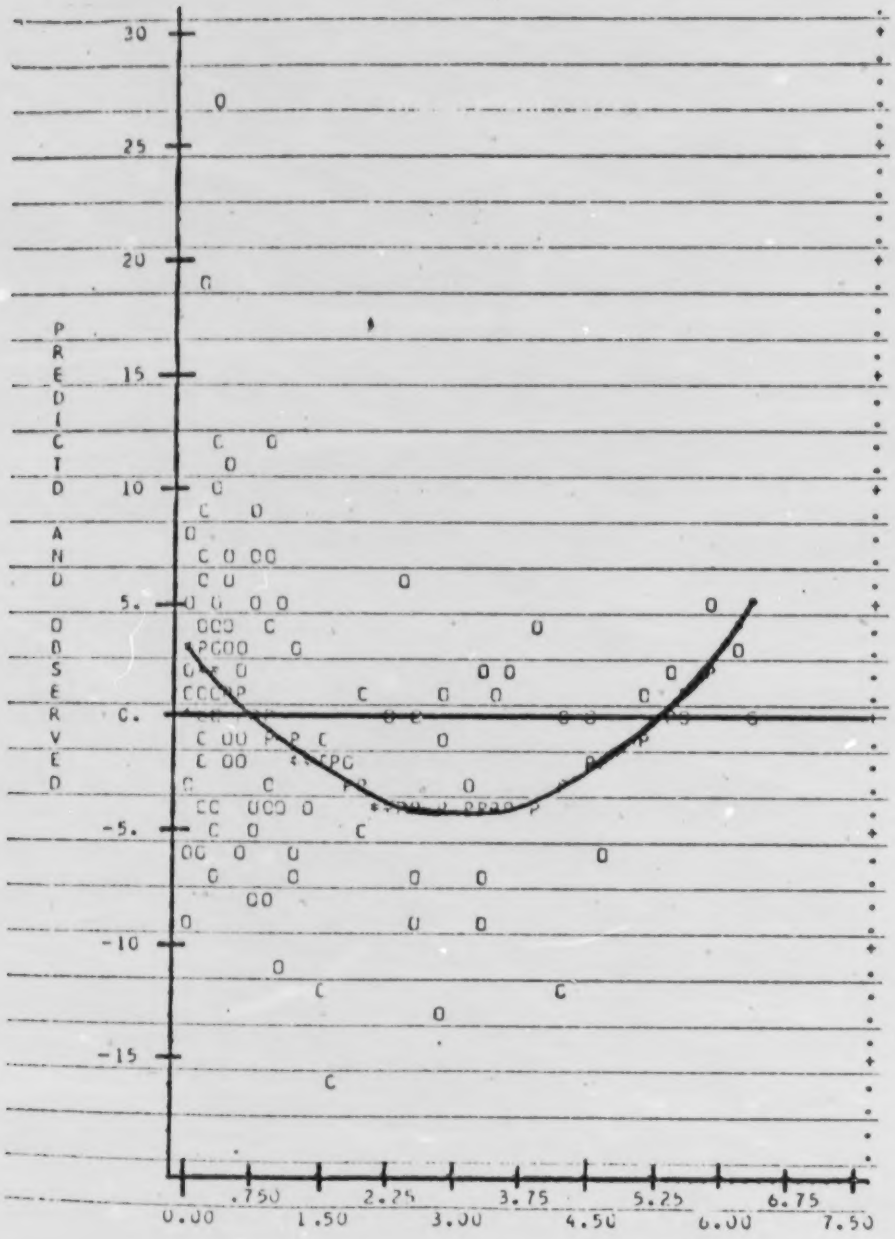

Figure 2. The process-product function for "one child with any adult" (M/109).

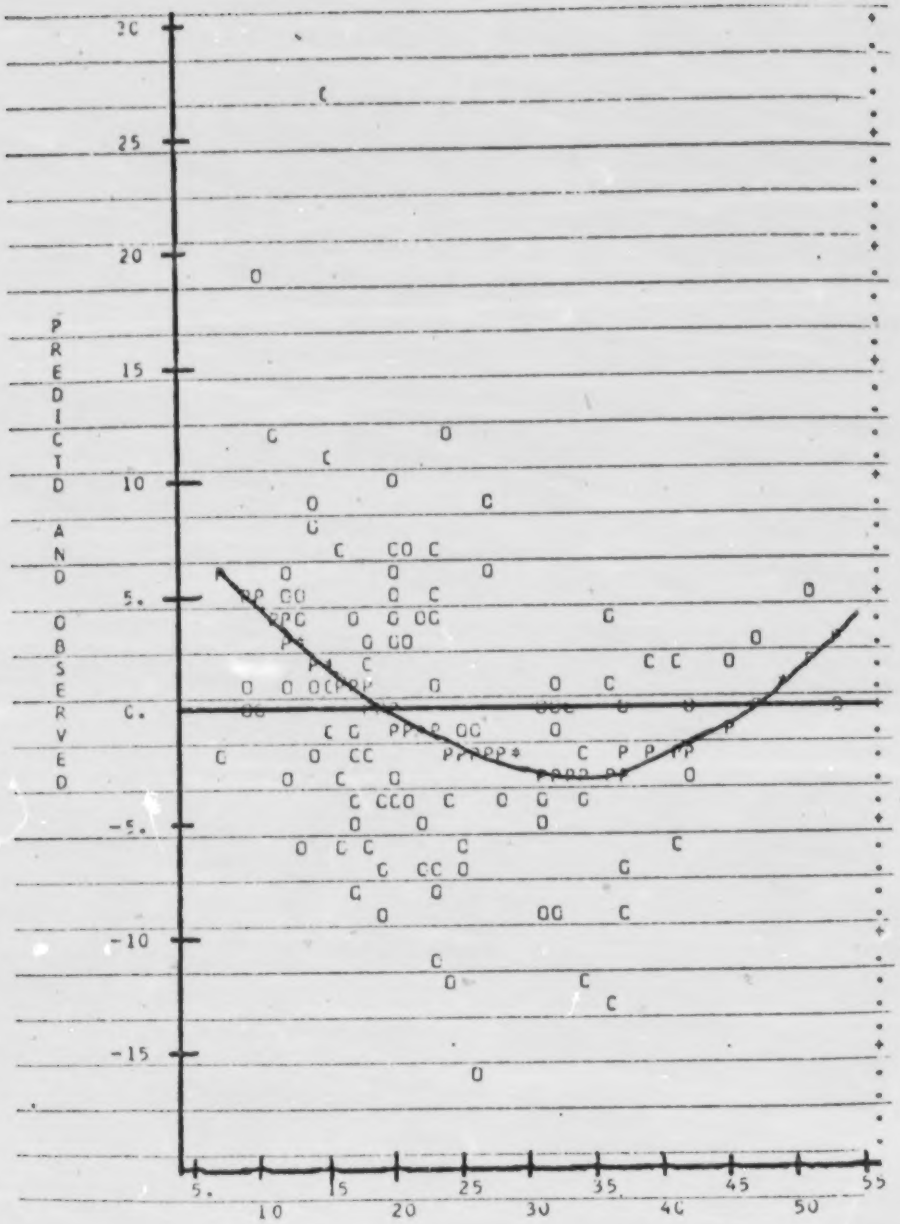

Figure 3. The process-product function for "classroom groupings: percent of adult-individual child interation time" (M/V2).

that, for an individual child, either many child-adult contacts or none at all seem to be associated with maximum mathematics achievement. On the other hand, as shown in Figure 4, the number of children involved in mathematics on all of the observed days (var. 140) has an inverted U-shaped relation to mathematics achievement. Although Stallings and Kaskowitz reported that this variable "also had high positive correlations with all of the mathematics test scores" (p. 283), the present reanalysis results suggest that there may be optimum levels of child involvement in mathematics activities. However, because an outlier again is involved, these results must be regarded as tentative only.

The relationship between mathematics achievement and the percent of time a teacher interacts with one child in any type of mathematics groupings (var. V5) is illustrated in Figure 5 as a cubic function. There is the possibility, though perhaps a remote one, that the elimination of the outlier could result in an inverted U curve. As it stands, the data seem to imply that there is an optimal level of time that a teacher could spend interacting with a single child. But this relationship is in need of more study before conclusions can be drawn.

Each of the following variables--child/teacher and aide ratio (var. 15), percent of time the teacher was with individual children (var. V1), and percent of time the teacher interacted with one child in any type of reading groups (var. V7)--has a significant nonlinear relationship with reading residual scores. Figure 6, which presents the relationship between child/teacher and aide ratio (var. 15) and reading residual scores,

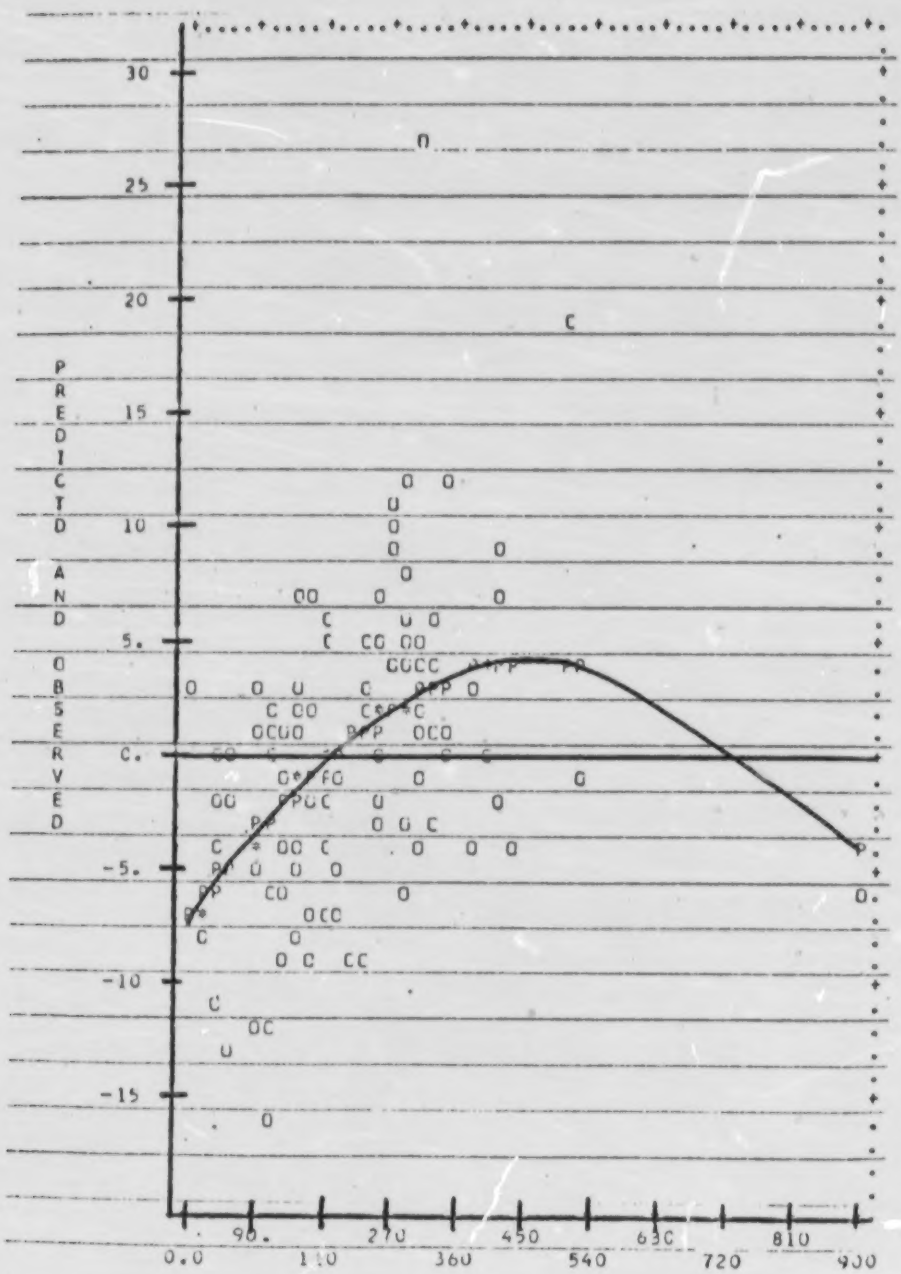

Figure 4. The process-product function for "total weight in math groupings" (M/140).

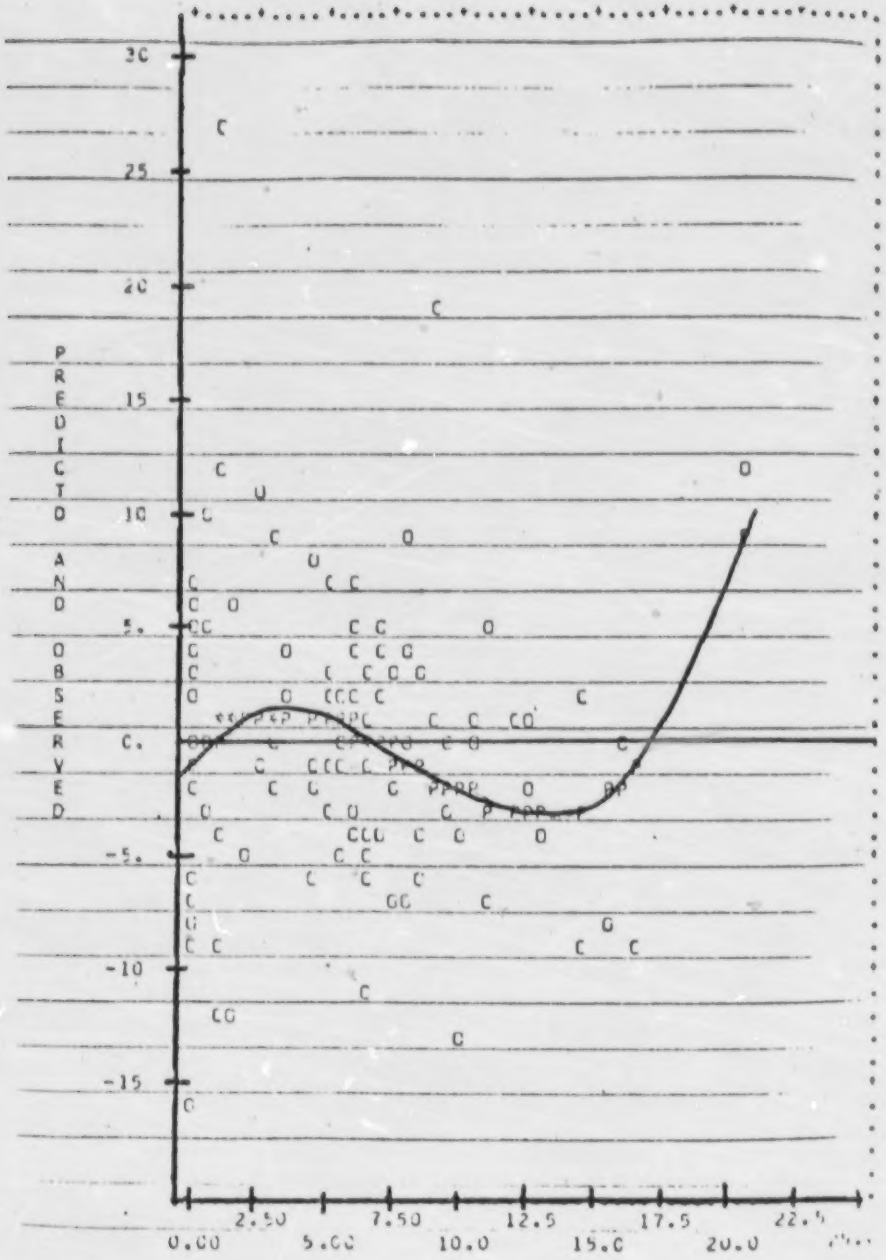

Figure 5. The process-product function for "math groupings: percent of teacher-individual child interaction time" (M/V5).

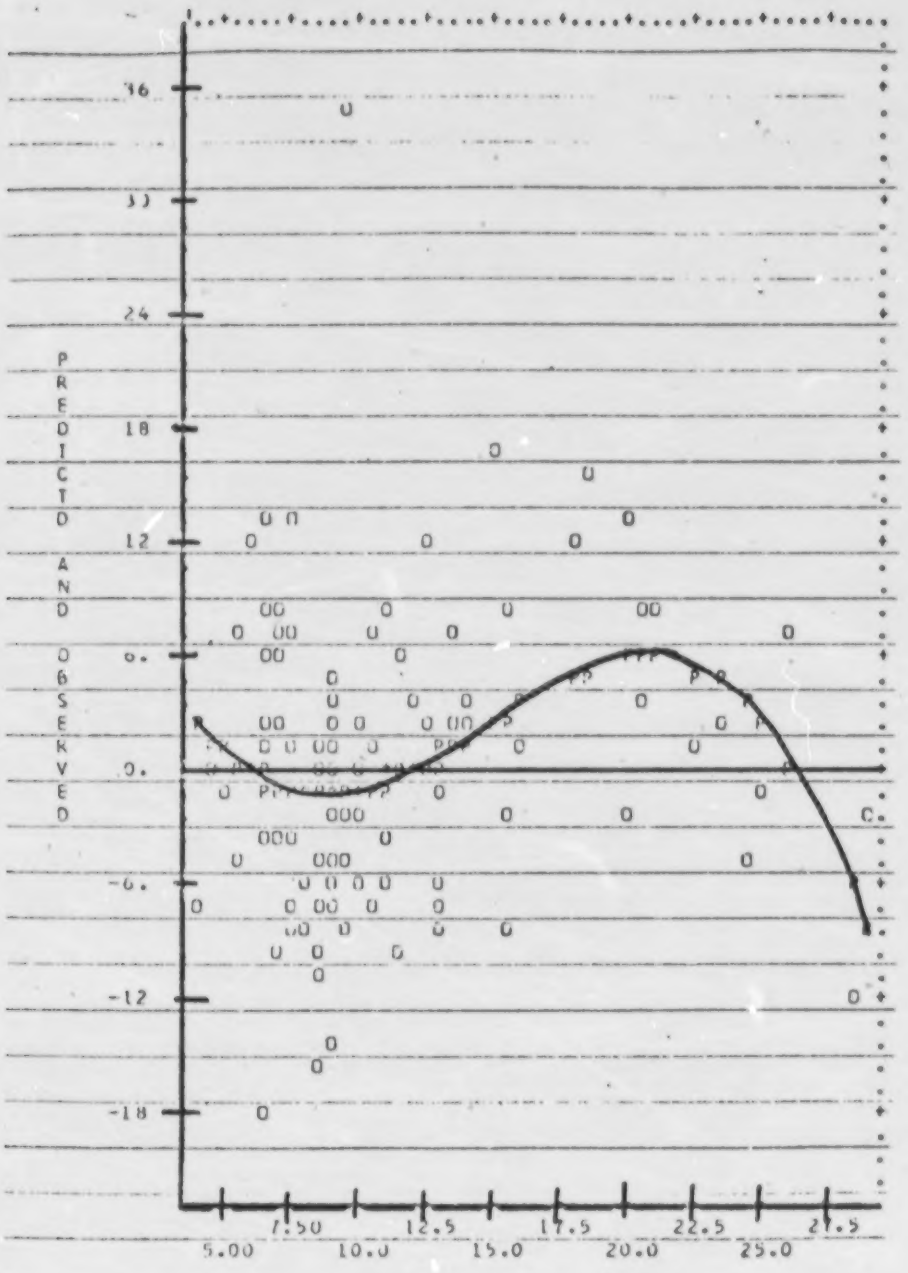

Figure 6. The process-product function for " child/teacher and aide ratio" (R/15).

shows that the optimum ratio is between fifteen and twenty-five children per teacher/aide. The cubic nature of this variable invites caution in interpretation since the function itself maybe due to an interaction effect. Figure 7, which is descriptive of the relationship between the percent of teacher time spent in interaction with individual children (var. V1) and reading residual scores, indicates that the optimum percent of teacher time that possibly should be spent in interaction with individual children is between 12-24 percent per class day. The relationship between the percent of time a child interacts with teachers in any type of reading group (var. V7) and reading residual scores (see Figure 8) was found to fit a quartic equation. While there seems to be a general trend for achievement to decline as the amount of teacher-individual contacts increase, there are enough deviations from this trend to indicate the need for additional analysis.

To date, the Stallings and Kaskowitz study has been a primary source of data for reviewers who attempt to synthesize study findings on teacher effectiveness or process-product research correlations between instructional organization variables and student achievement (e.g., Berliner & Rosenshine, 1977; Gow, 1977; Medley, 1978; Rosenshine, 1976, 1977). These reviewers have generally indicated that instances of children working alone, or of one or two children working with the teacher or aide, were consistently negatively correlated with achievement. These reanalysis results however, reveal that mathematics achievement increases as the percent of time one child is with any adult (var. 109) or as the proportion of the time adults are with individual children becomes very large (i.e., above 50 percent) (var. V2). The reasons for these findings are

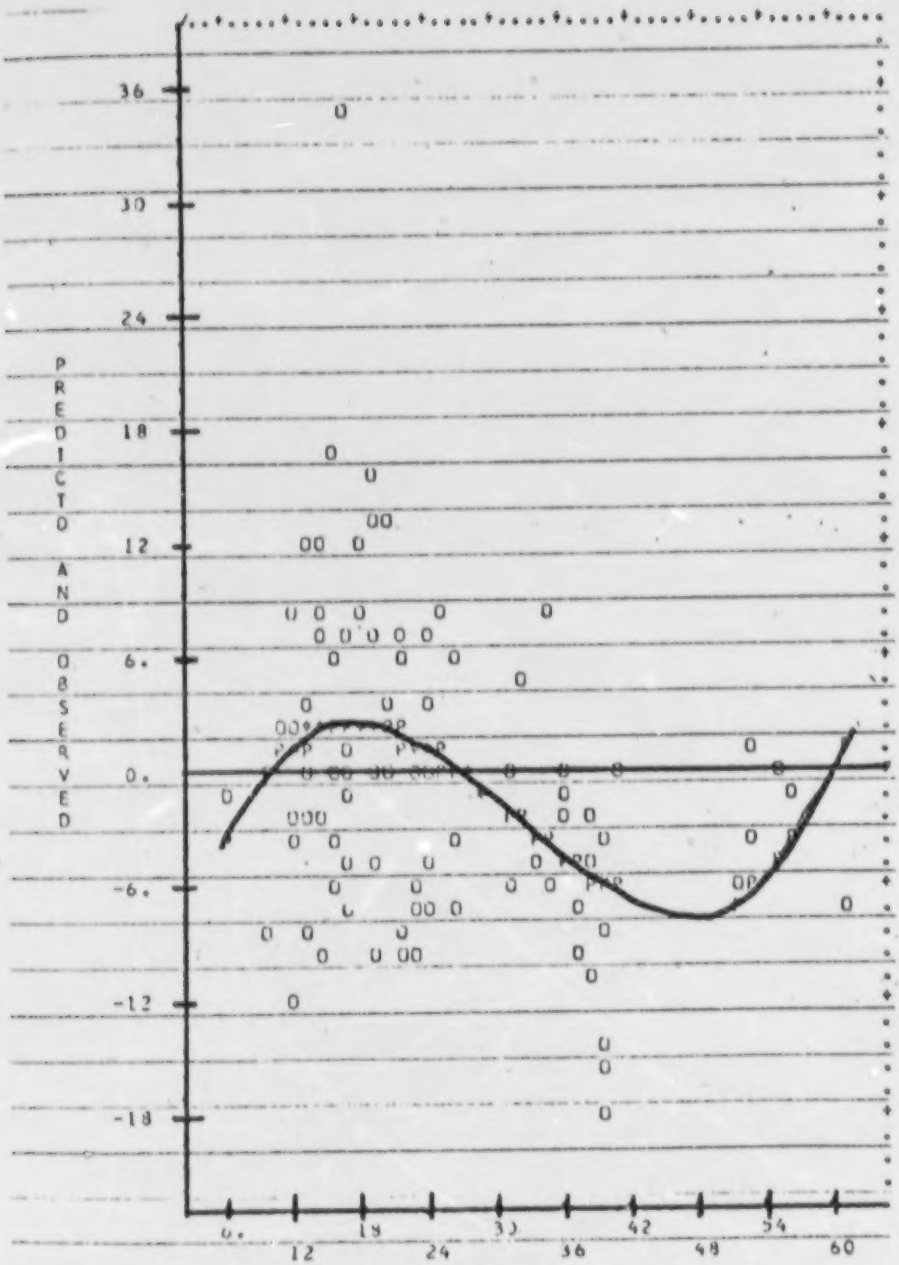

Figure 7. The process-product function for "classroom groupings: Percent of teacher-individual child interaction time" (R/V1).

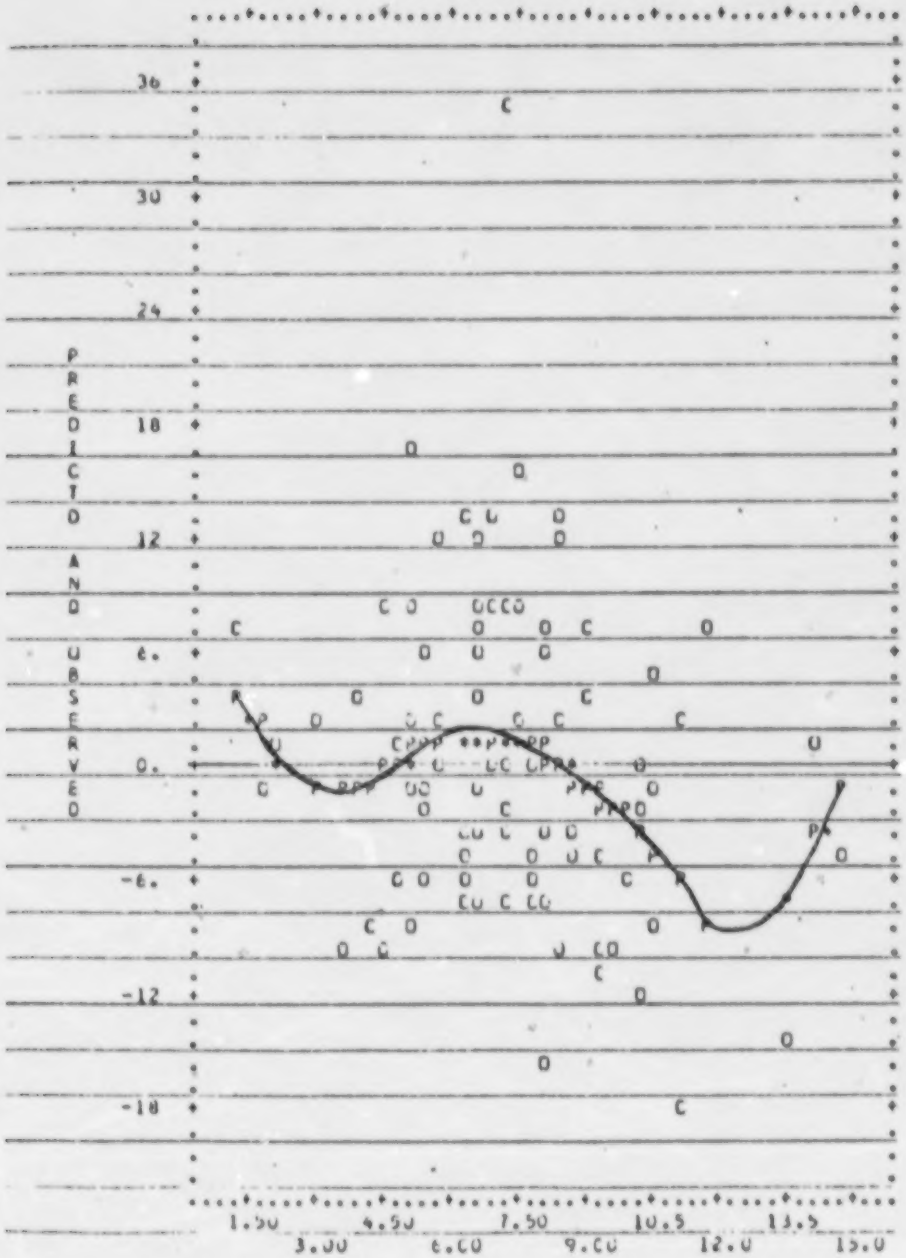

Figure 8. The process-product function for "reading groups: percent of teacher-individual child interaction" (R/V7).

not all clear since the nonlinear cubic relationships found between aggregated variables and achievement are generally difficult to interpret. This represents another set of relationships for which additional study is needed.

Monitoring

Monitoring is used here to refer to the supervising activities that teachers perform to maintain student on-task behaviors. A lack of monitoring behavior on the part of the teacher is sometimes inferred from student behavior. The two process variables listed in Table 3 for the monitoring construct, that is, "percent of time a child was without adults (V4)" and "child self-instruction, nonacademic (599c)," are suggestive of a lack of teacher monitoring behavior. Teachers may well object to such an assumption.

The first of these variables (V4) is a composite of "one child without adults," "two children without adults," "small group of children without adults," and "large group of children without adults." This complex variable has a quadratic relation with residualized mathematics and reading scores that may be best described as upright partial U-shaped curves. As shown in Figures 9 and 10, the functions for both mathematics and reading achievement indicate that residual scores drop rapidly with increases in the percent of time that children--regardless of groupings--are without adults; the scores level off at the 30 or 50 percent mark and show a very slight but perhaps not highly meaningful increase thereafter. This process-product relationship is essentially a negative one.

Table 3

Summary of Process-Product Relationships: Monitoring

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
V4	Percent of time a child was without adults	28.37	14.83	0.0 - 56.80	-.31/ω	.38	x^2	⌣	-.30/ω	.34	x^2	⌣
599c	Child self-instruction, nonacademic	4.57	5.43	0.0 - 35.55	.26		x		-.18		x	

*All "r" coefficients of ± .19 or above are significant at the $p < .05$ level. All "R" coefficients are significant at the $p < .05$ level.

ω: This variable is a new composite and was not studied as such in the primary analysis.

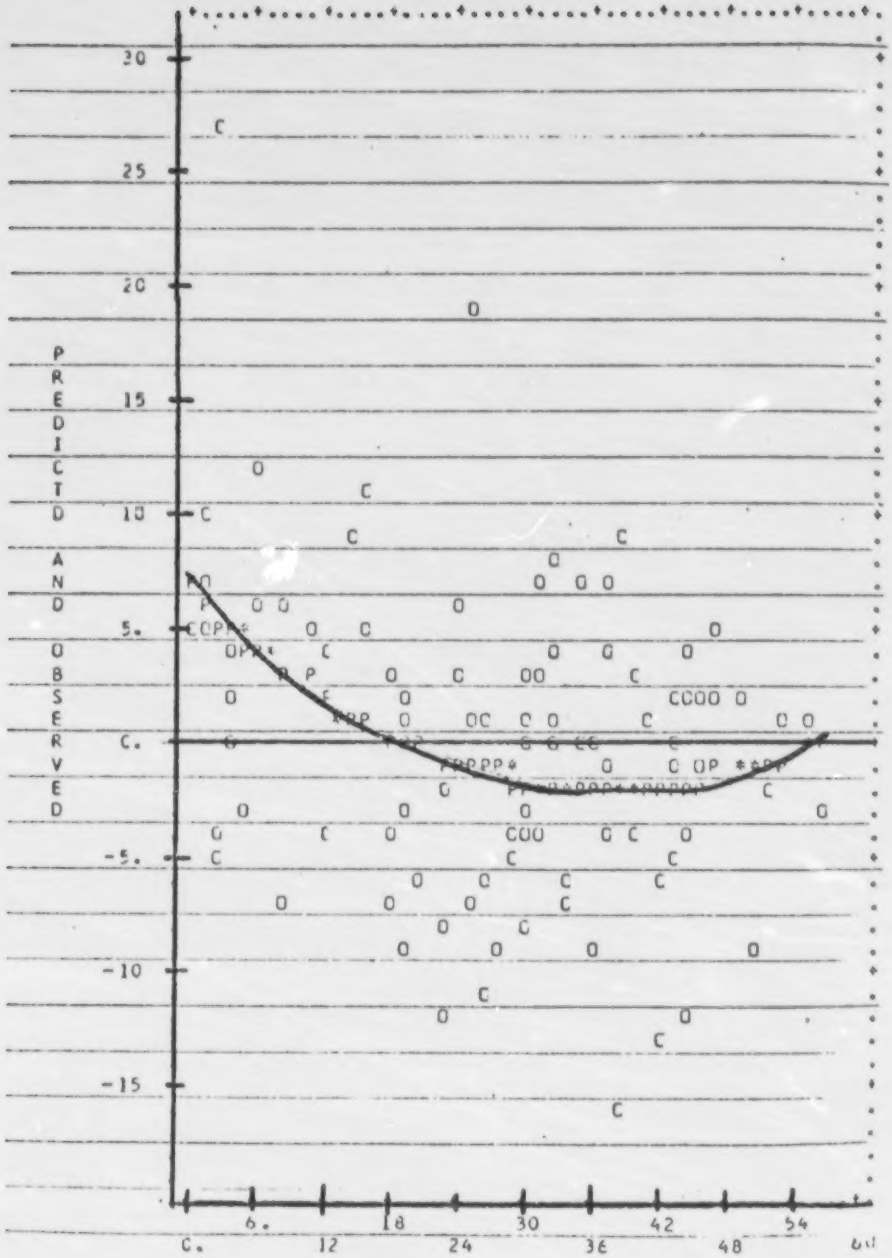

Figure 9. The process-product function for "percent of time a child was without adults" (M/V4)--as related with mathematics achievement.

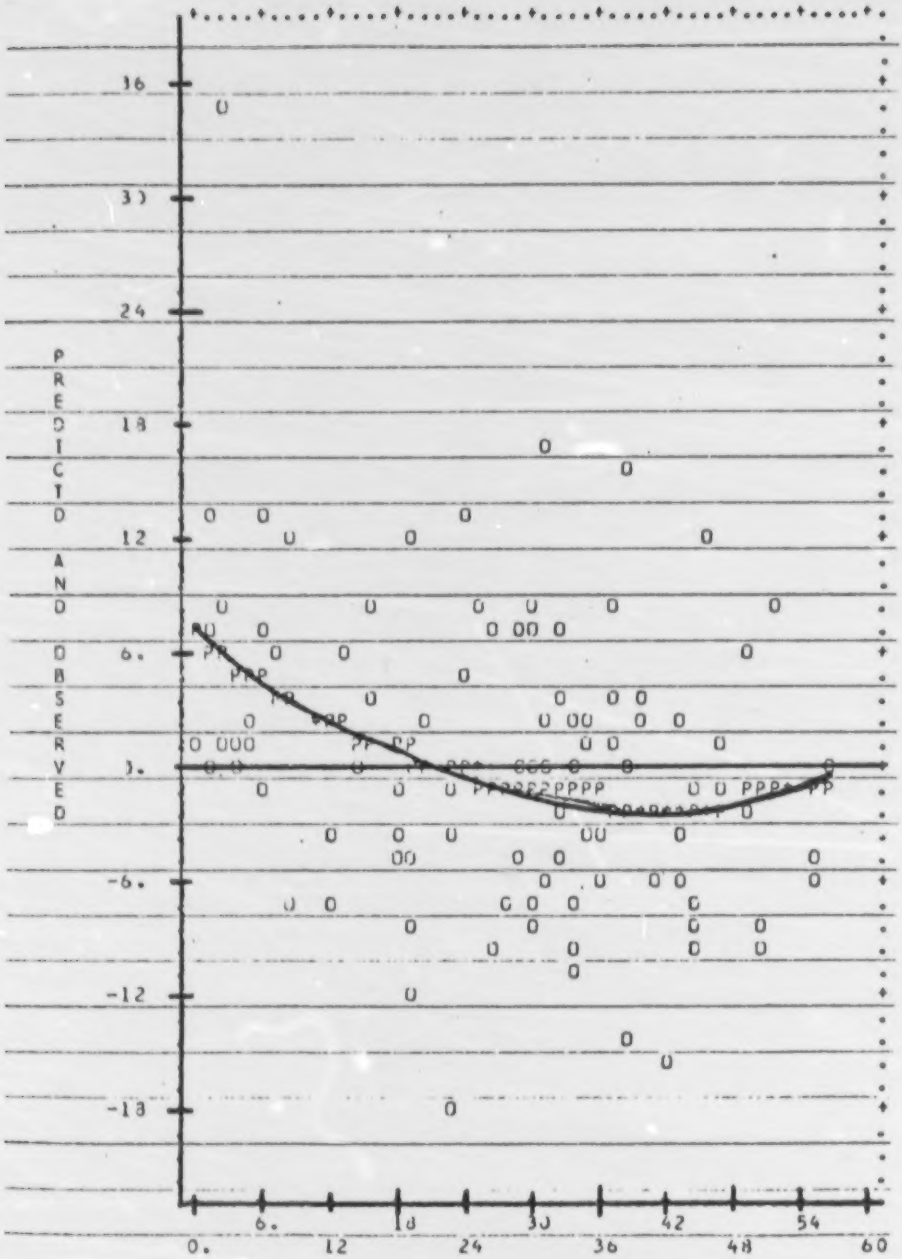

Figure 10. The process-product function for "percent of time a child was without adults" (R/V4)--as related with reading achievement.

The second variable, which is entitled "child self-instruction, nonacademic" (var. 599c)," is negatively and linearly related with residualized MAT scores.

Current research (e.g., McDonald & Elias, 1976; Stallings & Kaskowitz, 1974), says Rosenshine (1977), "shows that unsupervised students are less academically engaged than supervised students" (p. 14). This fact, Ruff suggests, may partially account for the negative correlations of lack of teacher monitoring with student achievement. The curvilinear results found here, especially because of their consistency across measures, should not be disregarded without further study. While the results are not necessarily out of line with previous findings, the slight upward turn in student achievement with lack of "monitoring" behaviors suggest that this variable may interact with other variables, or that the measure itself requires further refinement.

Management

According to Ruff, "management refers collectively to all the behaviors teachers exhibit to form the ground rules by which instruction and interaction occur in the classroom" (p. 26). The process variable listed in Table 4 for this construct, that is, "adults involved in classroom management (V9)," is a composite representing the percent of occasions in which teacher, aide, and volunteer were involved in classroom management. The correlation of this management variable with student achievement was low, negative, and linear.

Table 4

Summary of Process-Product Relationships: Management

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
V9	Adults involved in classroom management	8.40	6.98	0.0 - 37.22	-.07/ω		x		-.16/ω		x	

* All "r" coefficients of ± .19 or above are significant at the $p < .05$ level. All "R" coefficients are significant at the $p < .05$ level.

ω: This variable is a new composite and was not studied as such in the primary analysis.

The fact that this composite is negatively related to achievement is consistent with previous findings. For example, Medley's (1978) review suggests that teachers whose students show the most growth tend to devote less time to management behaviors than teachers whose students are generally low achieving.

Teacher Questioning

The term "instruction" is suggestive of a variety of transactions that occur between teachers and students and between students and materials. Verbal interactions are but one aspect of those transactions, and teacher questioning is but one aspect of the variety of verbal exchanges that may occur during instruction. The process variables listed in Table 5, that is, "adult academic commands/requests and direct questions to children (451a, 582c)" and "adult open-ended questions to children (452a, 583c)," reflect teacher questioning behavior with the observational focus being either on the teacher or the child.

Direct questioning is positively and linearly related to reading achievement, but curvilinearly related to achievement in mathematics. These relationships are consistent in that they hold regardless of the focus (adult or child) of the observation. The nature of the curvilinear functions for mathematics achievement may best be described as inverted partial U-shapes. Figures 11 and 12 show that these curves are very similar in shape. Such a function suggests that increases in direct questioning behaviors (and in academic commands/requests) are associated with increases in mathematics

Table 5

Summary of Process-Product Relationships: Teacher Questioning

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
451a	Adult academic commands/ requests and direct questions to children	7.25	3.39	0.13 - 15.31	.25	.30	x^2	⌒	.26		x	
582c	Adult academic commands/ requests and direct questions to children	2.15	1.70	0.0 - 8.80	.32	.36	x^2	⌒	.35		x	
452a	Adult open-ended questions to children	0.36	0.34	0.0 - 1.73	-.03		x		-.08		x	
583c	Adult open-ended questions to children	0.10	0.21	0.0 - 1.50	-.04		x		-.05		x	

*All "r" coefficients of ± .19 or above are significant at the $p < .05$ level. All "R" coefficients are significant at the $p < .05$ level.

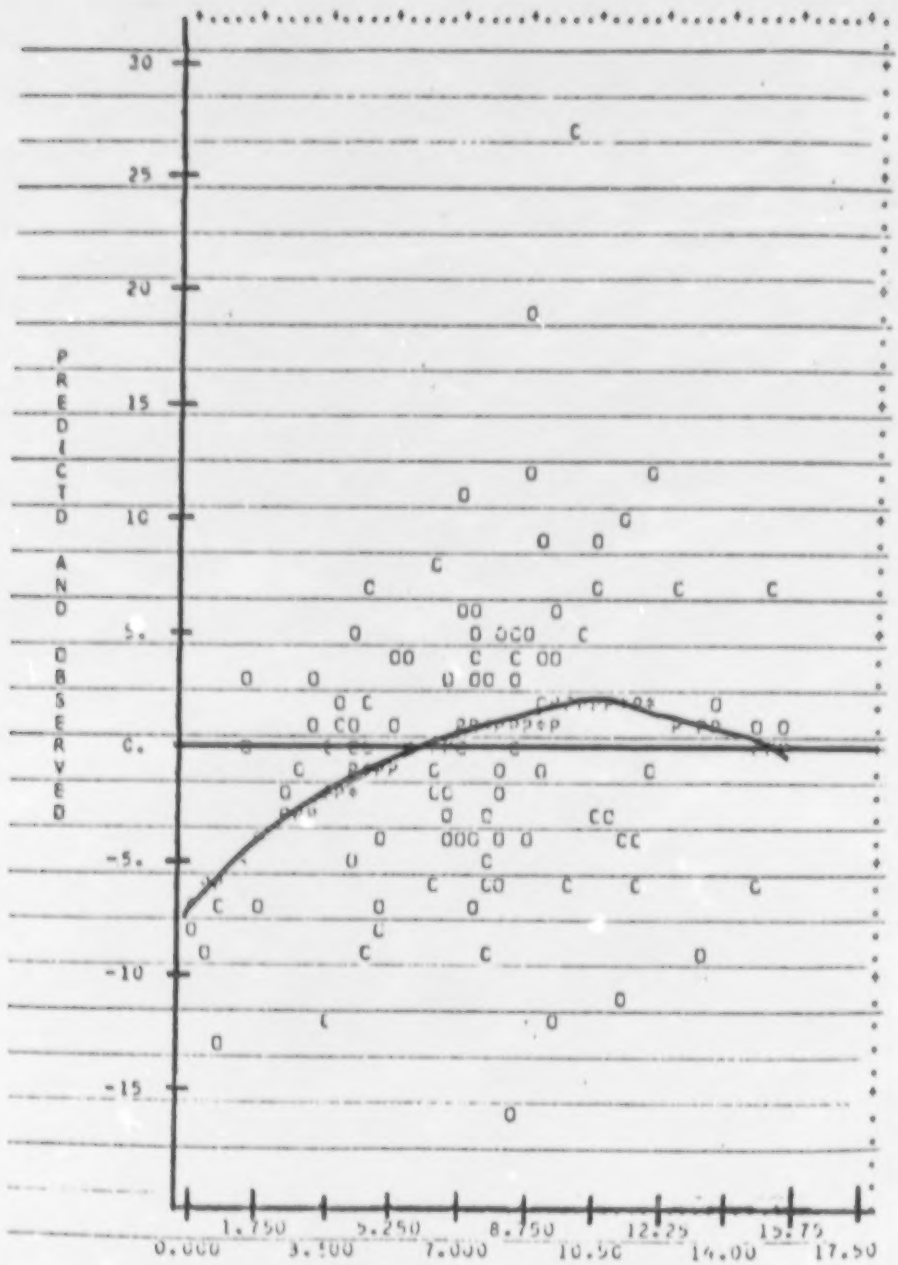

Figure 11. The process-product function for "adult academic commands/requests and direct questions to children" (M/451a).

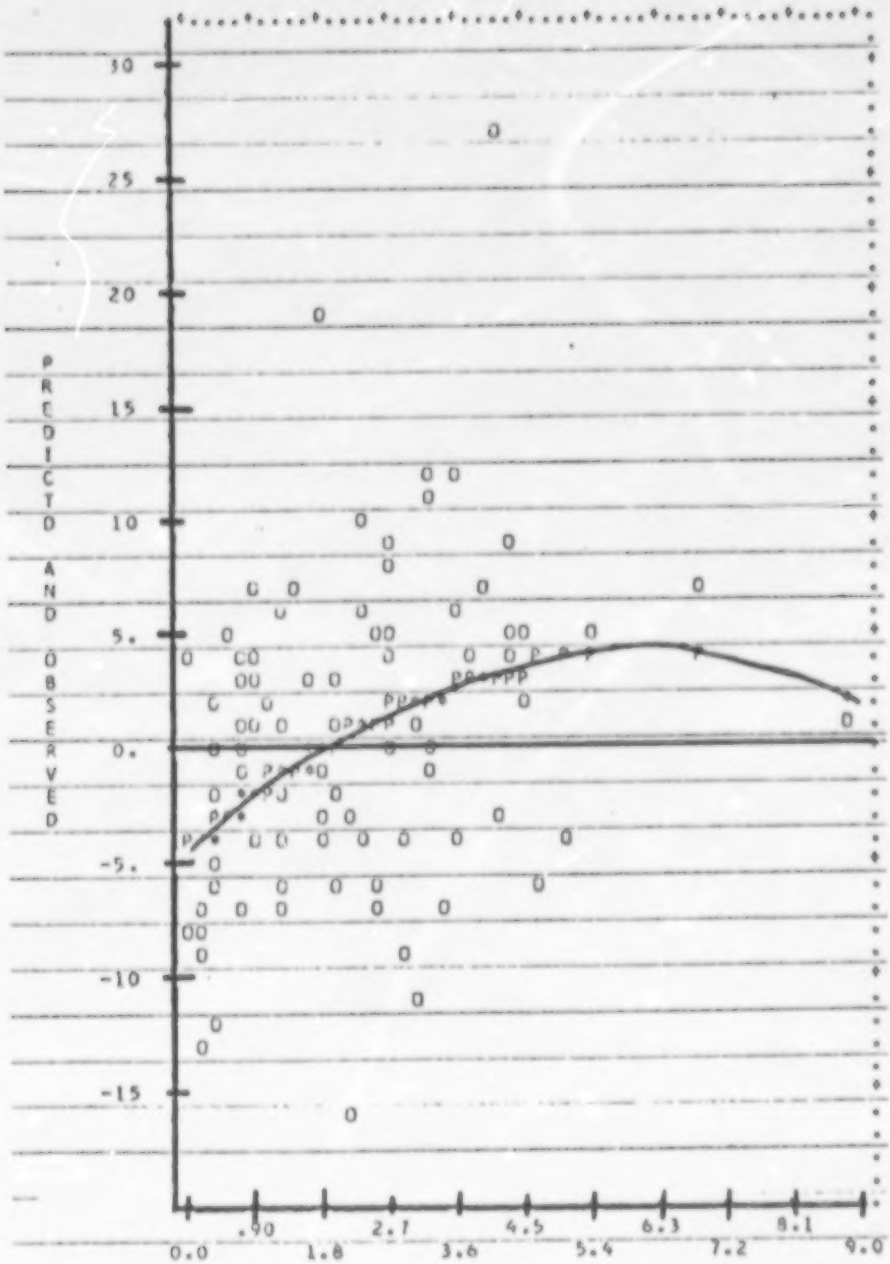

Figure 12. The process-product function for "adult academic commands/requests and direct questions to children" (M/582c).

achievement until some maximum is reached; thereafter, they are associated with diminished marginal returns. The implications of such functions are not unlike those for inverted U shapes, though less negative; that is, some moderate amount of direct questioning seems optimal and more is simply not more effective.

Table 5 also indicates that adult open-ended questions (vars. 452a and 583c) have near zero correlations with achievement as measured in this study.

It is not fully clear how the "direct question" variable relates to prior research. Medley (1978), for example, indicates that effective teachers of low-SES pupils ask more lower order questions than ineffective ones do. However, it seems fairly certain that the three facets of this variable--namely, commands, requests, and direct questions--occurred at such low frequency that Stallings and Kaskowitz probably had to combine them. More research and/or analysis is required to understand better the meaning of these current findings.

Teachers' Reaction to Pupil Responses

This construct is concerned with teacher behaviors during exchanges with students. The process variable listed in Table 6, "adult response to child's question with a question (453a, 584c)," with the focus either on the teacher or the child, appears to fall within this construct.

An examination of the linear correlations in Table 6 reveals a low to near zero process-product association for all four correlations.

Table 6

Summary of Process-Product Relationships: Teacher Reactions to Pupil Responses

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D	Range	r	R	Degree	Shape	r	R	Degree	Shape
453a	Adult response to child's question with a question	0.10	0.15	0.0 - 0.78	-.05/§		x		.04/§	.25	x^2	⌣
584c	Adult response to child's question with a question	0.04	0.07	0.0 - .50	.16/§		x		.14		x	

*All "r" coefficients of ± .19 or above are significant at the $p < .05$ level. All "R" coefficients are significant at the $p < .05$ level.

§: Stallings and Kaskowitz did not report these partial correlation coefficients.

However, an upright partial U-shaped nonlinear association was found between adult-focused observations on this variable (var. 453a) and reading achievement. An examination of Figure 13, which displays the curve, suggests that there may be a threshold effect; that is, this particular type of teacher reaction seems not to be facilitative initially, but does seem to become facilitative as the frequency of the behavior increases.

Inverted U shapes, as well as negative and positive linear associations, have been found by Brophy and Evertson (1974a, 1974b) for reading achievement and the process variable: "repeats, rephrases, or asks new questions." The degree of relationship between current finding and those of Brophy and Evertson is difficult to assess, since the Stallings and Kaskowitz variable is related only to one facet of the Brophy and Evertson variable.

Pupil Response Patterns

Teacher-student interactions involve pupil responses as well as teacher reactions. The process variables listed in Table 7, that is, "all child open-ended questions (450a)", "child's extended response to questions (454a, 585c)," and "all child-task related comments (587c)" represent pupil response patterns.

Curvilinear functions describe parts of all but one of the pupil response variables listed above. The all child open-ended questions (var. 450a) has a low, negative, nonsignificant, linear association with reading achievement and a cubic association, which is largely uninterpretable,

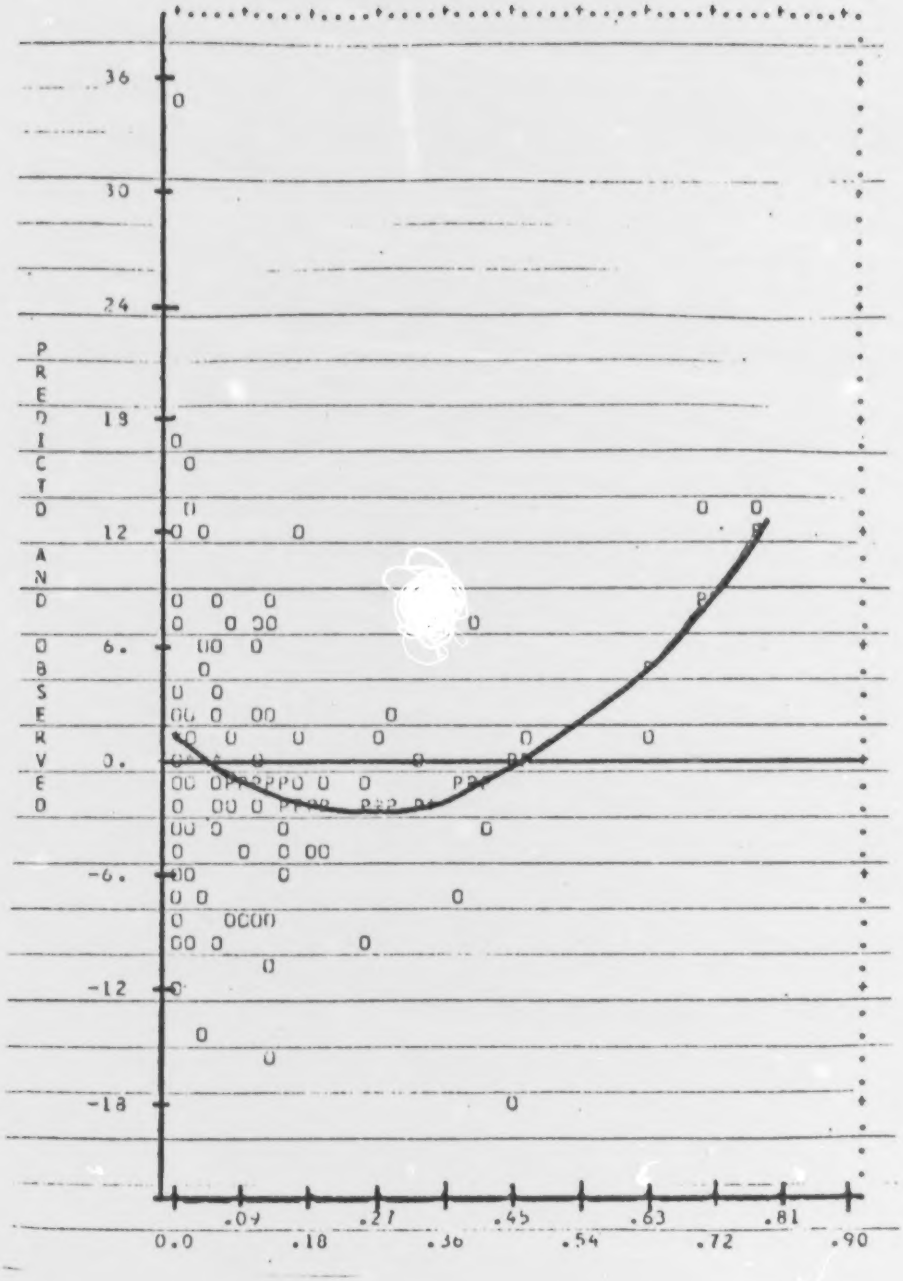

Figure 13. The process-product function for "adult response to child's question with a question" (R/453a).

Table 7

Summary of Process-Product Relationships: Pupil Response Patterns

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
450a	All child open-ended questions	0.01	0.02	0.0 - 0.14	-.10/-.09	.23	x^3		-.17		x	
454a	Child's extended response to questions	0.46	0.54	0.0 - 2.73	.35		x		.21/ §	.40	x^4	
585c	Child's extended response to questions	0.37	0.29	0.0 - 1.15	.26	.34	x^2		.02/ §		x	
587c	All child-task related comments	3.46	2.87	0.11 - 14.56	-.03/-.04		x		-.07/ §		x	

*All "r" coefficients of ± .19 or above are significant at the $p < .05$ level. All "R" coefficients are significant at the $p < .05$ level.

§: Stallings and Kaskowitz did not report these partial correlation coefficients.

with mathematics (see Figure 14). Since this behavior (var. 450a) occurs so infrequently, no firm conclusions can be drawn at this time.

The child's extended response to questions/adult focus variable (var. 454a) has a moderate, positive, and linear association with mathematics achievement and a quartic association with reading achievement (see Figure 15). The child's extended response to questions/child focus variable (var. 585c) has a near zero association with reading achievement and a quadratic association with mathematics achievement. Figure 16 shows that this latter extended response variable is best described as a inverted partial U-shaped curve. Such a function suggests that increases in the number of children's extended responses to questions are associated with increases in mathematics achievement until some maximum is reached, and thereafter there are diminished returns in mathematics achievement gains. On the average, one extended response per class period seems sufficient to maximize outcomes; more than this seems to produce mildly reduced gains. The all child-task related comments (var. 587c), the last variable listed, appears to be unrelated to student outcomes.

Rosenshine (1976), drawing primarily from Stallings and Kaskowitz's data, concluded that pupil responses to direct academic questions are associated positively with achievement, whereas pupil responses to nonacademic and open-ended questions are negatively associated with achievement. The results of the current reanalysis suggest that the relationships are much more complex.

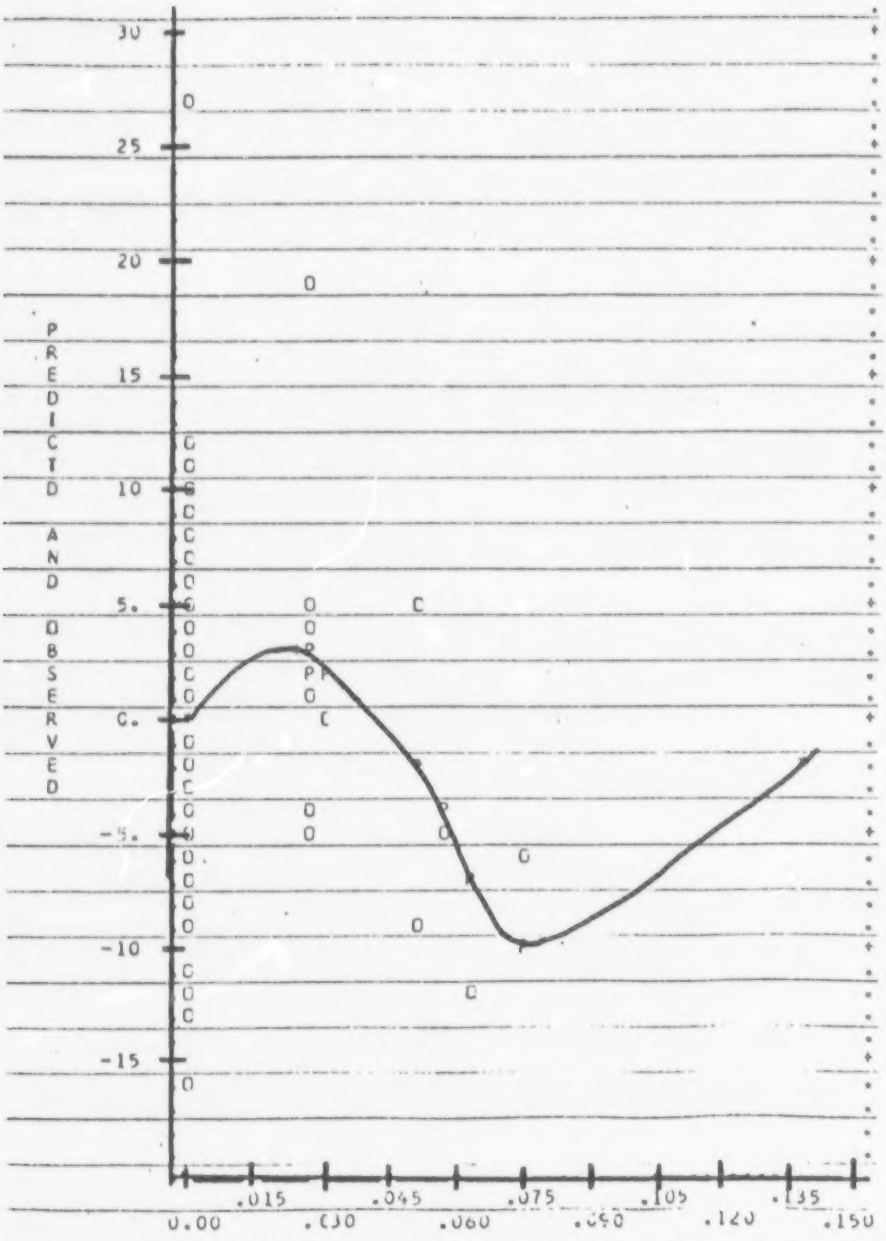

Figure 14. The process-product function for "all child open-ended questions" (M/450a).

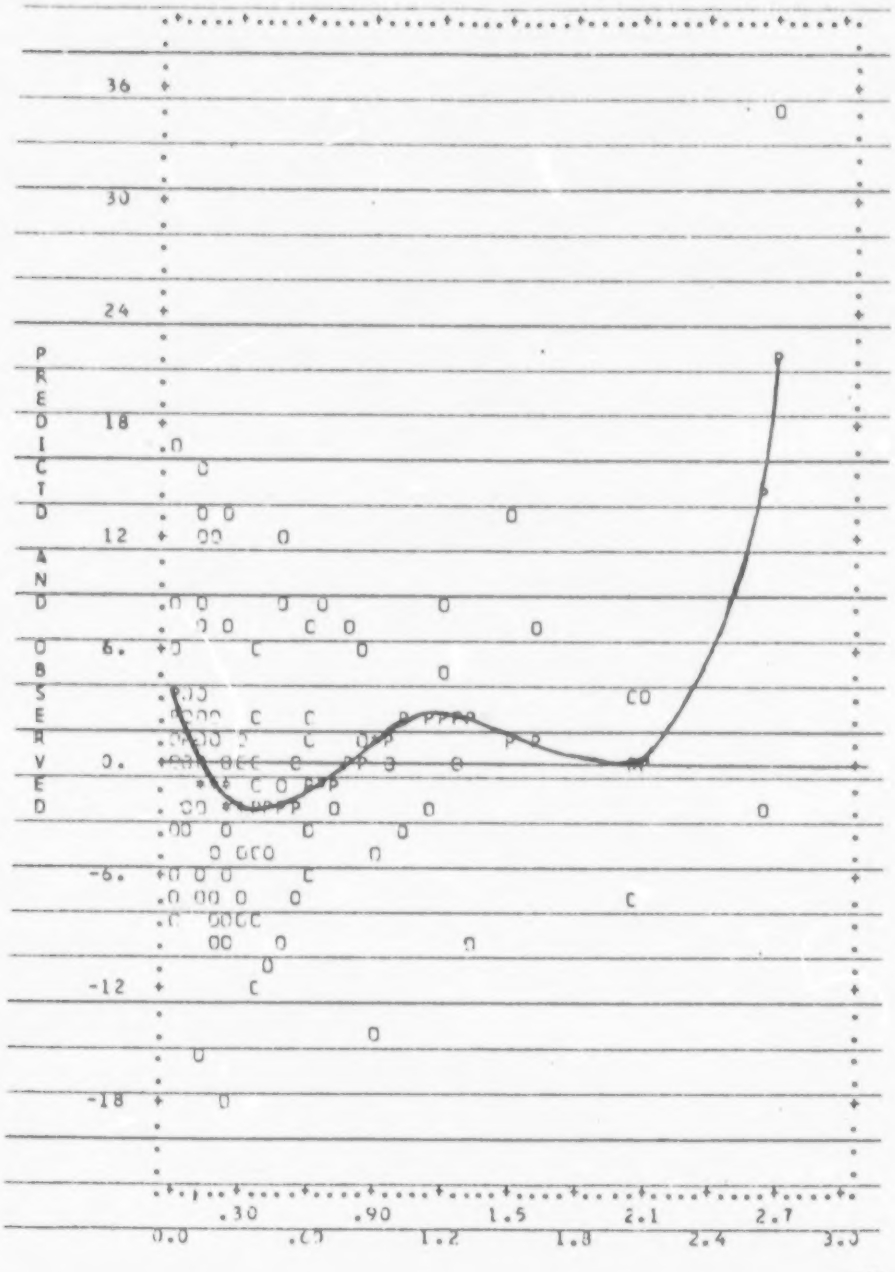

Figure 15. The process-product function for "child's extended response to questions" (R/454a).

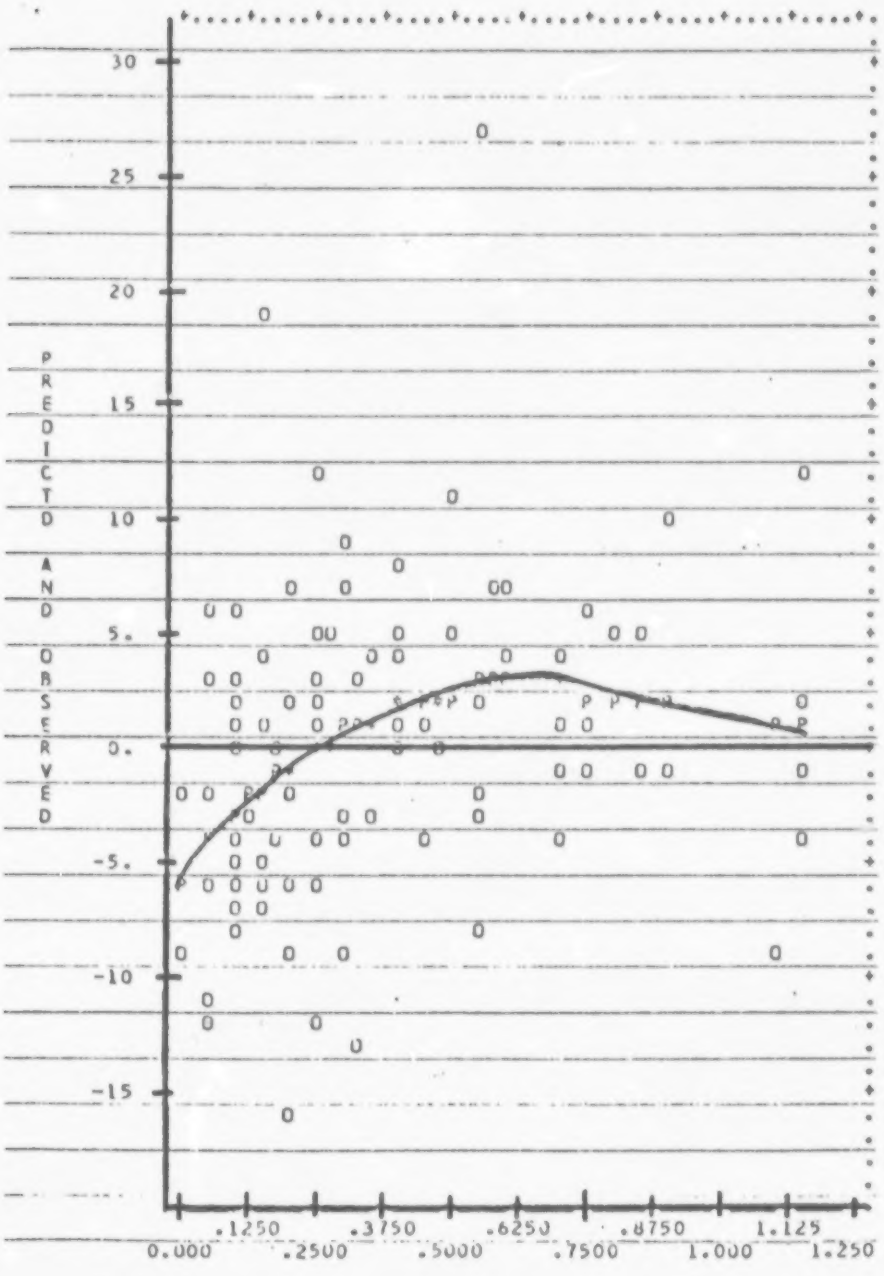

Figure 16. The process-product function for "child's extended response to questions" (M/585c).

Teaching Activities

By teaching activities, Ruff (1978) means the types of instructional activities that occur in the classroom, or what Rosenshine (1976, 1977) and Berliner and Rosenshine (1977) have discussed under the heading of "ways of spending direct instructional time."

Of the seven process variables listed in Table 8, only "variety of materials used (V10)"--which is a composite of percent of time the following instructional materials were used in academic activities: TV, audiovisual equipment, exploratory materials, math or science equipment, tests, workbooks, and puzzles and games--showed a nonlinear relationship to achievement. This variable has a low correlation with mathematics achievement, but an inverted U-shape relationship with reading achievement. Figure 17, which shows the functional relationship between this process variable and reading achievement, implies that infrequent use of materials in general, as well as frequent use of a variety of materials, are both dysfunctional; moderate use of either a variety of materials or relatively frequent use of few materials--these issues are confounded in the composite--appears to be optimal. This type of relationship does not appear to have been addressed by any reviewer and, therefore, will not be discussed further.

Structure/Control

Teachers differ in the degree to which they arrange instruction and control student freedom. Tikunoff, Berliner, and Rist (1975) define

Table 8

Summary of Process-Product Relationships: Teaching Activities

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
44	Total number different resource categories coded "present" over three days	21.02	3.71	0.0 - 28.00	-.03		x		-.19		x	
45	Total number different resource categories coded "used today" over three days	14.65	4.37	0.0 - 25.00	-.03		x		-.10/§		x	
82	Wide variety of activities, concurrent	1.84	0.52	0.98 - 3.33	-.06/-.07		x		-.18		x	
83	Wide variety of activities, over one day	6.49	1.83	3.0 - 11.33	-.12/-.13		x		-.30		x	
V10	Variety of materials used	15.51	8.22	1.19 - 45.00	-.08/ω		x		-.02/ω	.26	x^2	⌒
471a	Adults attentive to large group	2.96	2.99	0.0 - 14.84	-.07		x		.02		x	
586c	All adult instruction	1.71	1.11	0.05 - 6.25	.08/.05		x		.12		x	

*All "r" coefficients of ± .19 or above are significant at the p < .05 level. All "R" coefficients are significant at the p < .05 level.

ω: This variable is a new composite and was not studied as such in the primary analysis.

§: Stallings and Kaskowitz did not report these partial correlation coefficients.

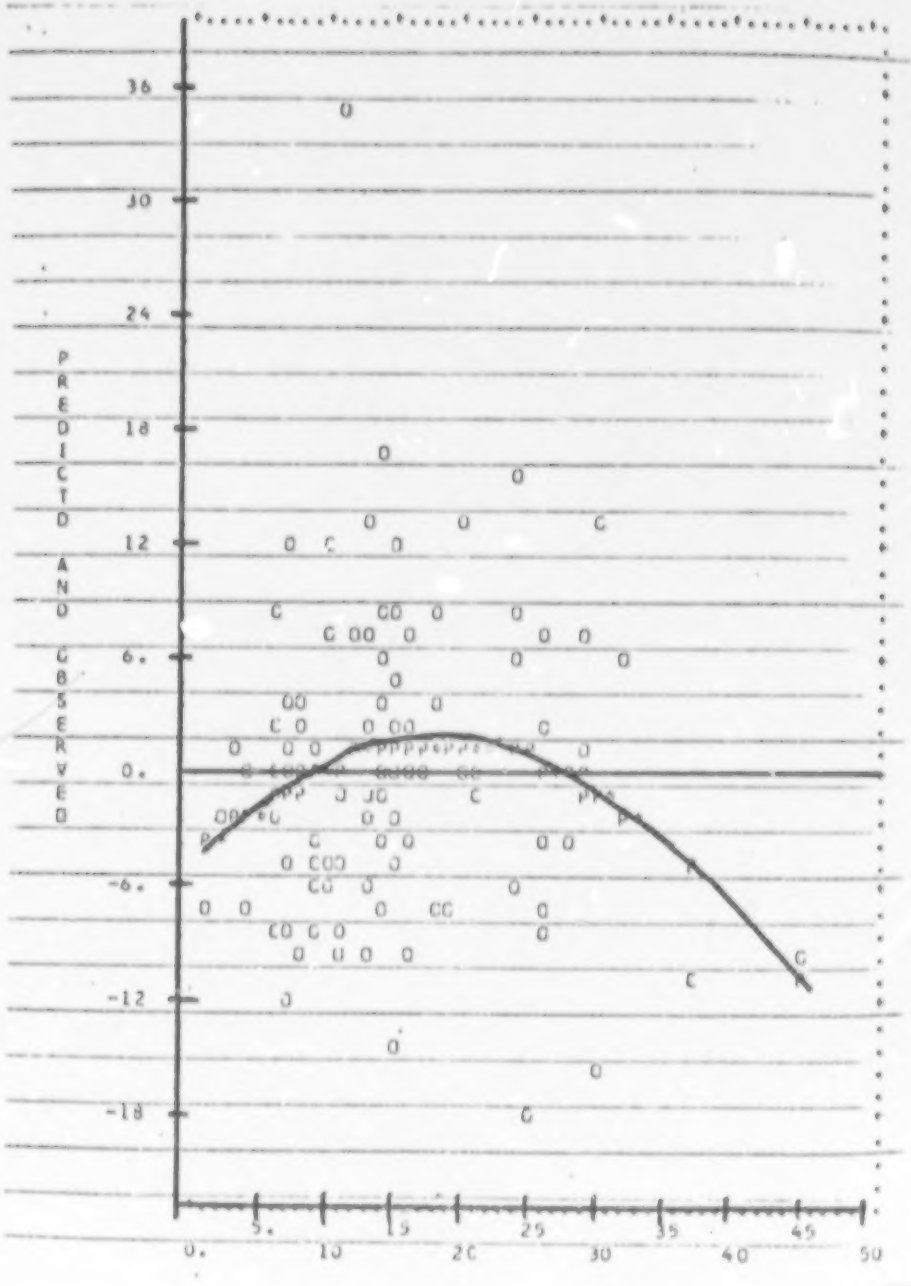

Figure 17. The process-product function for "variety of materials used" (R/V10).

structure as: "the teacher preparation of students for a particular lesson" (p. 382). Such teacher behaviors directly and/or indirectly control student behavior. The Stallings and Kaskowitz variable "child selection (24)" is a weighted aggregate of four variables, namely: (1) assigned seating for at least part of the day, (2) children select their own seating locations, (3) teacher assigns children to groups, and (4) children select their own work groups. In general, the relationship between child selection and achievement is a negative one (see Table 9); the association with mathematics is linear, and the association with reading is curvilinear. The curvilinear function is described as a negatively accelerating curve (i.e., \ ). Figure 18 shows that reading achievement does not decline until the weighted scale value exceeds 2 points; thereafter, the decline is quite steep.

Soar and Soar (1976), in describing results across four studies, indicate that the relationship between teacher permissiveness and achievement is essentially curvilinear, with moderate amounts being optimal. The current results provide some support for their findings.

Feedback

Information in respect to the correctness of a child's response or behavior is treated as "feedback." Five process variables, as listed in Table 10, are examined in this reanalysis; the second and last two have both an adult and child focus: "adult neutral corrective feedback, academic (499a)," "all adult positive corrective feedback (457a, 588c),"

Table 9

Summary of Process-Product Relationships: Structure/Control

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
24	Child selection	1.44	1.79	0.0 - 4.0	-.09		x		-.26	.36	x^2	⌒

*All "r" coefficients of ± .19 or above are significant at the $p < .05$ level. All "R" coefficients are significant at the $p < .05$ level.

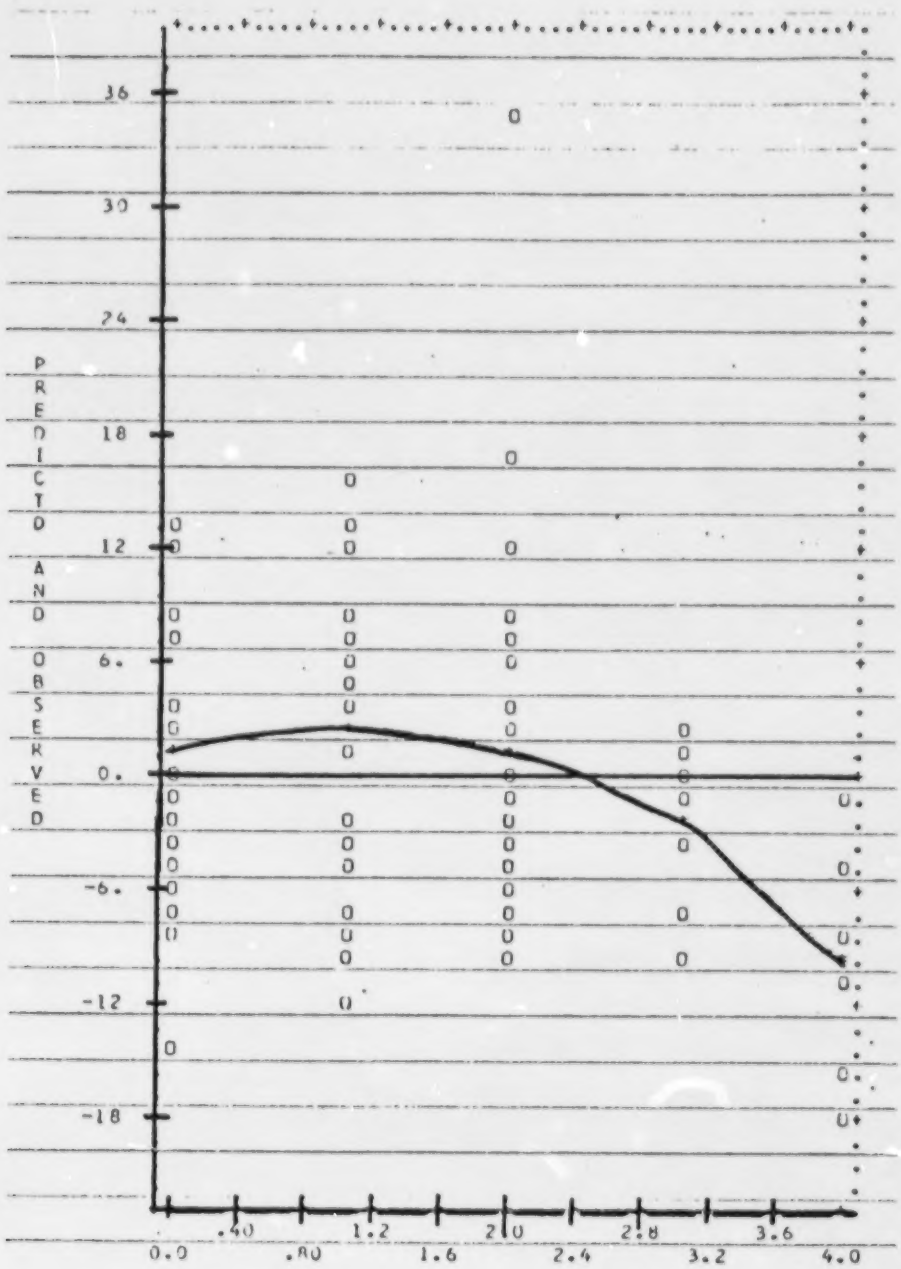

Figure 18. The process-product function for "child selection" (R/24).

Table 10

Summary of Process-Product Relationships: Feedback

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
449a	Adult neutral corrective feedback, academic	0.89	1.23	0.0 - 5.23	.23		x		.23	.32	x^4	∼
457a	All adult positive corrective feedback	2.42	1.20	0.45 - 6.93	.38		x		.14/ §		x	
588c	All adult positive corrective feedback	0.54	0.40	0.0 - 2.10	.31		x		.15/ §		x	
458a	All adult negative corrective feedback	0.15	0.28	0.0 - 2.18	.05/§		x		-.14/§	.21	x^4	∼
465a	Adult feedback to children for behavior	1.31	0.86	0.03 - 4.35	.03/ §		x		.09/§		x	
596c	Adult feedback to children for behavior	0.28	0.25	0.0 - 1.20	.07/ §		x		-.08/ §	.22	x^2	∪
470a	All adult neutral corrective feedback	1.56	1.67	0.0 - 9.35	.13	.30	x^4	∼	.15/§	.36	x^4	∼
601c	All adult neutral corrective feedback	0.23	0.29	0.0 - 1.60	.10/ §		x		-.02/ §		x	

*All "r" coefficients of ± .19 or above are significant at the p < .05 level. All "R" coefficients are significant at the p < .15 level.

§: Stallings and Kaskowitz did not report these partial correlation coefficients.

"all adult negative corrective feedback (458a)," "adult feedback to children for behavior (465a, 596c)," and "all adult neutral corrective feedback (470a, 601c)."

The adult neutral corrective feedback, academic variable (var. 499a) has a positive and linear relationship with mathematics achievement and a quartic relationship that is largely uninterpretable with reading achievement (see Figure 19). The all adult positive corrective feedback variables (var. 457a, 588c) are linearly related to both reading and mathematics achievement. The all adult negative corrective feedback variable (var. 458a) has a quartic relationship with reading achievement. The adult feedback to children for behavior/child-focus variable (var. 596c), which essentially has an upright U shape, implies that moderate amounts of feedback for behavior are not academically facilitating, but extremes of the behavior are. It is unclear as to why this should be the case (see Figure 20). The all adult neutral corrective feedback/adult focus (var. 470a) has a quartic relationship with both mathematics and reading achievement; but such relationships cannot easily be interpreted.

Rosenshine (1976, 1977) has indicated that in the Stallings and Kaskowitz study, both teacher praise and criticism are effective when academically focused. He also notes that teacher feedback is negatively related to student achievement when nonacademically focused. This latter observation may be in need of reexamination, given the fact that an upright U-shaped function was found for "adult feedback to children for behavior" (var. 596c).

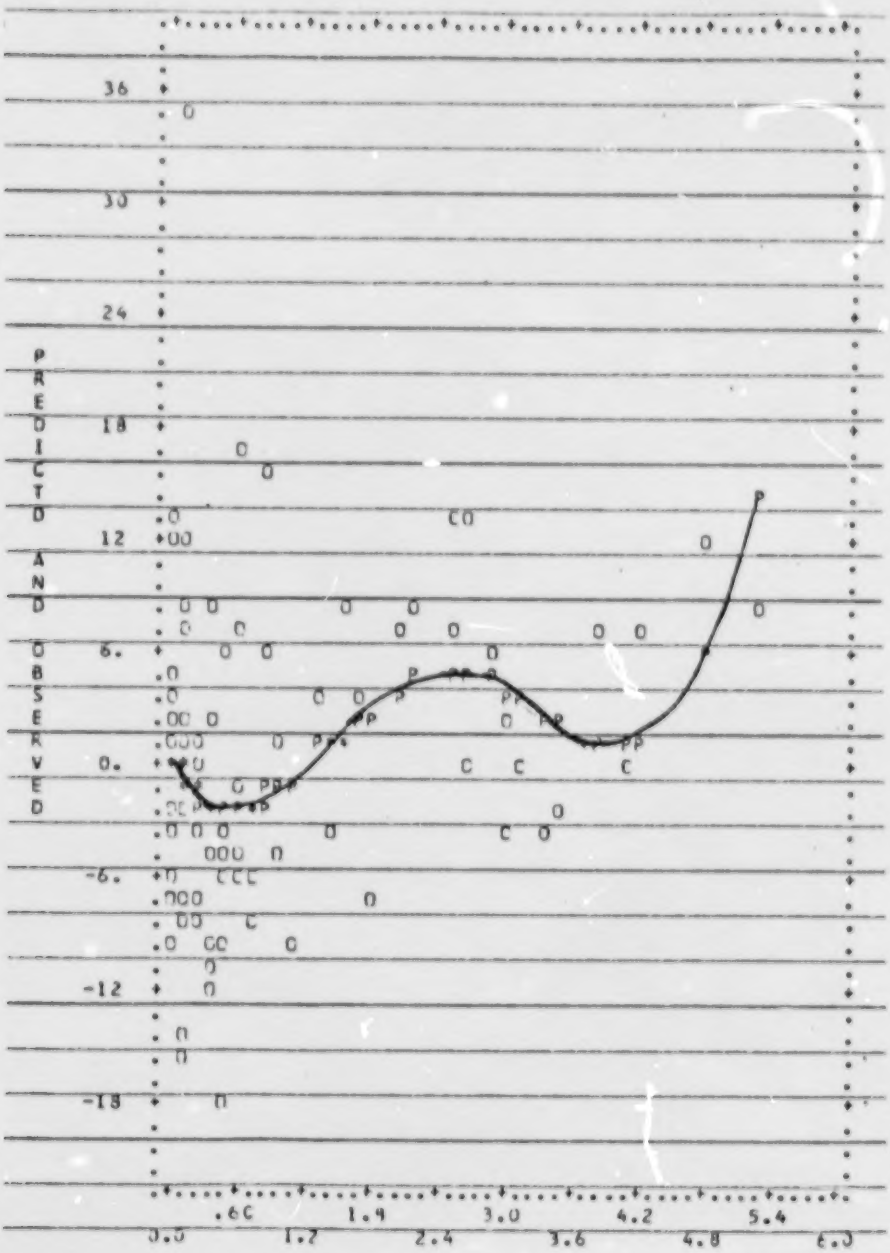

Figure 19. The process-product function for "adult neutral corrective feedback, academic" (R/449a).

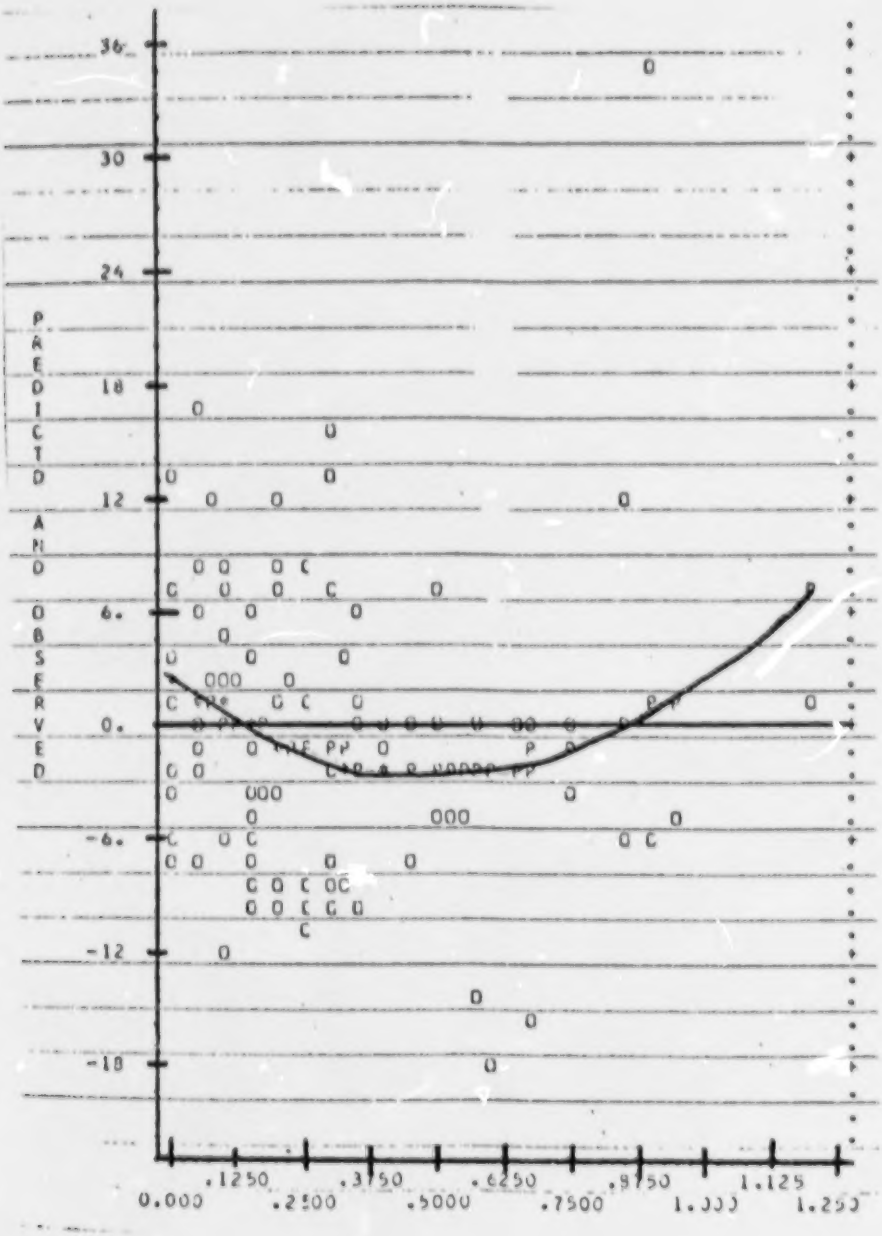

Figure 20. The process-product function for "adult feedback to children for behavior" (R/596c).

Qualities of the Environment

Qualities of the environment refer to the affective climate of the classroom. Six process variables as listed in Table 11 are examined for this reanalysis; of these, the third and fourth variable have both an adult and child focus. The variables are as follows: "all child positive affect (460a)," "all positive behavior (462a)," "child self-esteem (466a, 597c)," "child cooperation (467a, 598c)," "all negative behavior (594c)," and "child attentive (595c)."

The all child positive affect, all positive behavior, and all negative behavior variables (vars. 460a, 462a, 594c) have a negative and linear relationship with achievement.

Child self-esteem, both adult and child focused (vars. 466a, 597c), has a cubic relationship with both mathematics and reading achievement. Child self-esteem is an aggregate composed at least of child statements of self-worth and child's extended response to questions; the latter itself is an aggregate, which only adds to the difficulty of interpreting these outcomes. The functions displayed on Figures 21 and 22 suggest that some amount of child self-esteem prior to the midrange is associated with relatively high achievement; surprisingly, increasing levels of "self-esteem" are associated with decreasing levels of growth, until some minimum is reached and an upward turn occurs. For reading achievement, the highest levels of "self-esteem" are associated with the greatest gains in achievement. It is suspected that a number of variables are in interaction relative to this variable.

Table 11

Summary of Process-Product Relationships: Qualities of Environment

Process Variables					Mathematics				Reading			
No.	Name	Mean	S.D.	Range	r	R	Degree	Shape	r	R	Degree	Shape
460a	All child positive affect	0.51	0.73	0.0 - 4.57	-.11/§		x		-.06/§		x	
462a	All positive behavior	1.11	1.13	0.0 - 7.74	-.15/§		x		-.13/§		x	
466a	Child self-esteem	6.67	4.60	1.00 - 19.03	-.17/§	.29	x^3	~	-.06/§	.31	x^3	~
597c	Child self-esteem	6.84	4.65	1.06 - 19.24	-.17/§	.28	x^3	~	-.06/§	.35	x^3	~
467a	Child cooperation	1.58	1.79	0.0 - 9.60	.21	.45	x^4	~	.13/§	.46	x^4	~
598c	Child cooperation	3.45	2.96	0.0 - 14.72	-.07/-.03		x		-.07/-.12		x	
594c	All negative behavior	0.25	0.47	0.0 - 3.65	.01/-.11		x		-.18			
595c	Child attentive	11.74	5.67	0.0 - 27.50	-.09/-.07	.33	x^3	~	-.12/§	.21	x^2	~

*All "r" coefficients of ± .19 or above are significant at the $p < .05$ level. All "R" coefficients are significant at the $p < .05$ level.

§: Stallings and Kaskowitz did not report these partial correlation coefficients.

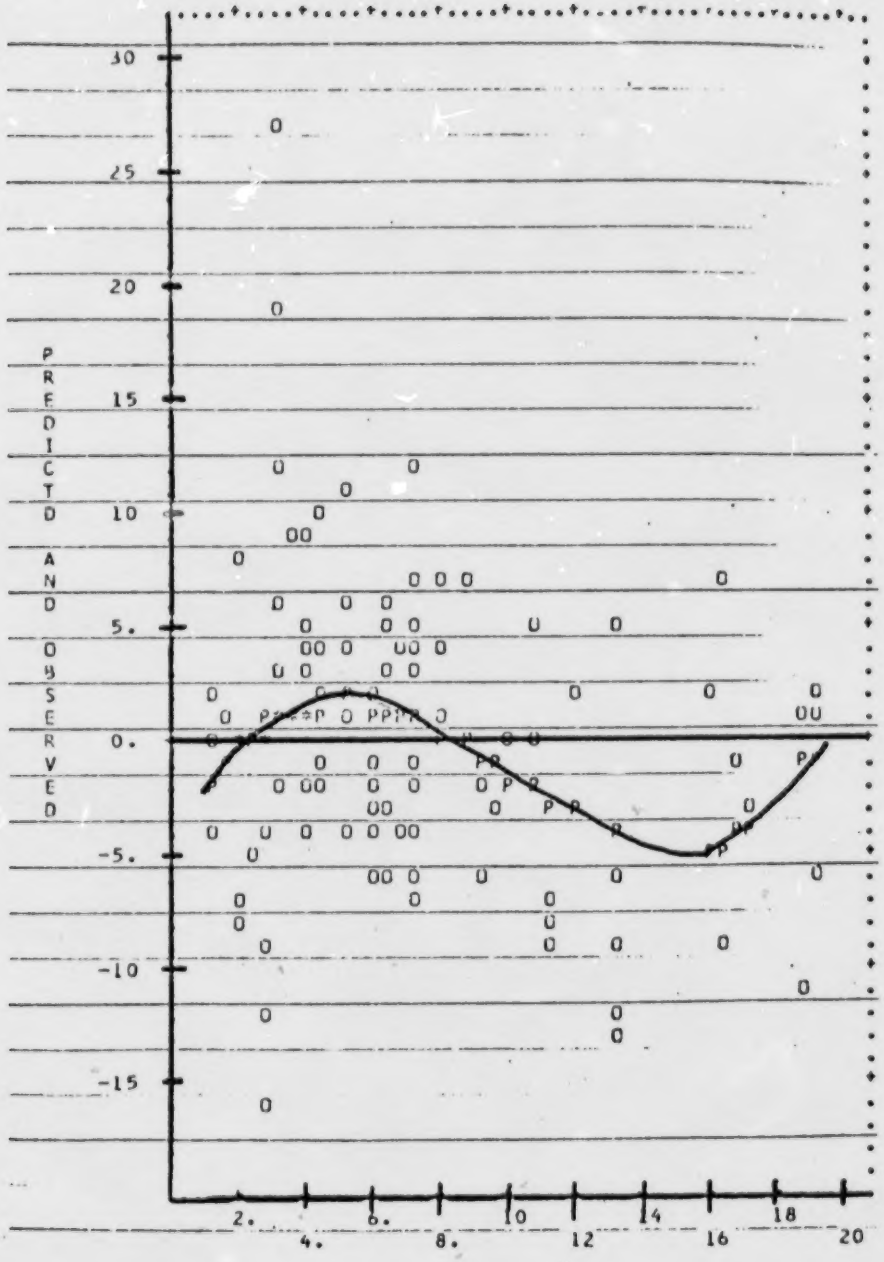

Figure 21. The process-product function for "child self-esteem" (M/597c)--as related with mathematics achievement.

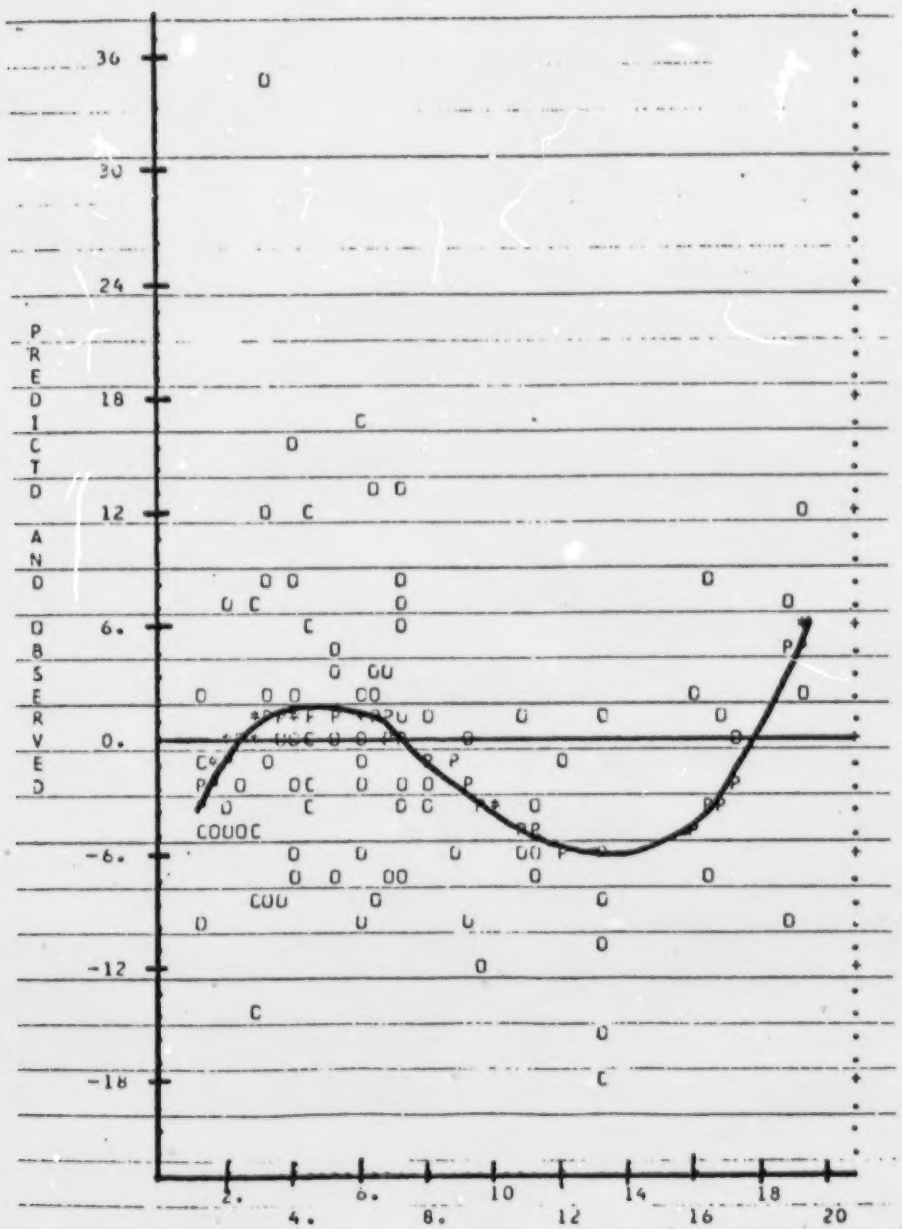

Figure 22. The process-product function for "child self-esteem" (R/597c)--as related with reading achievement.

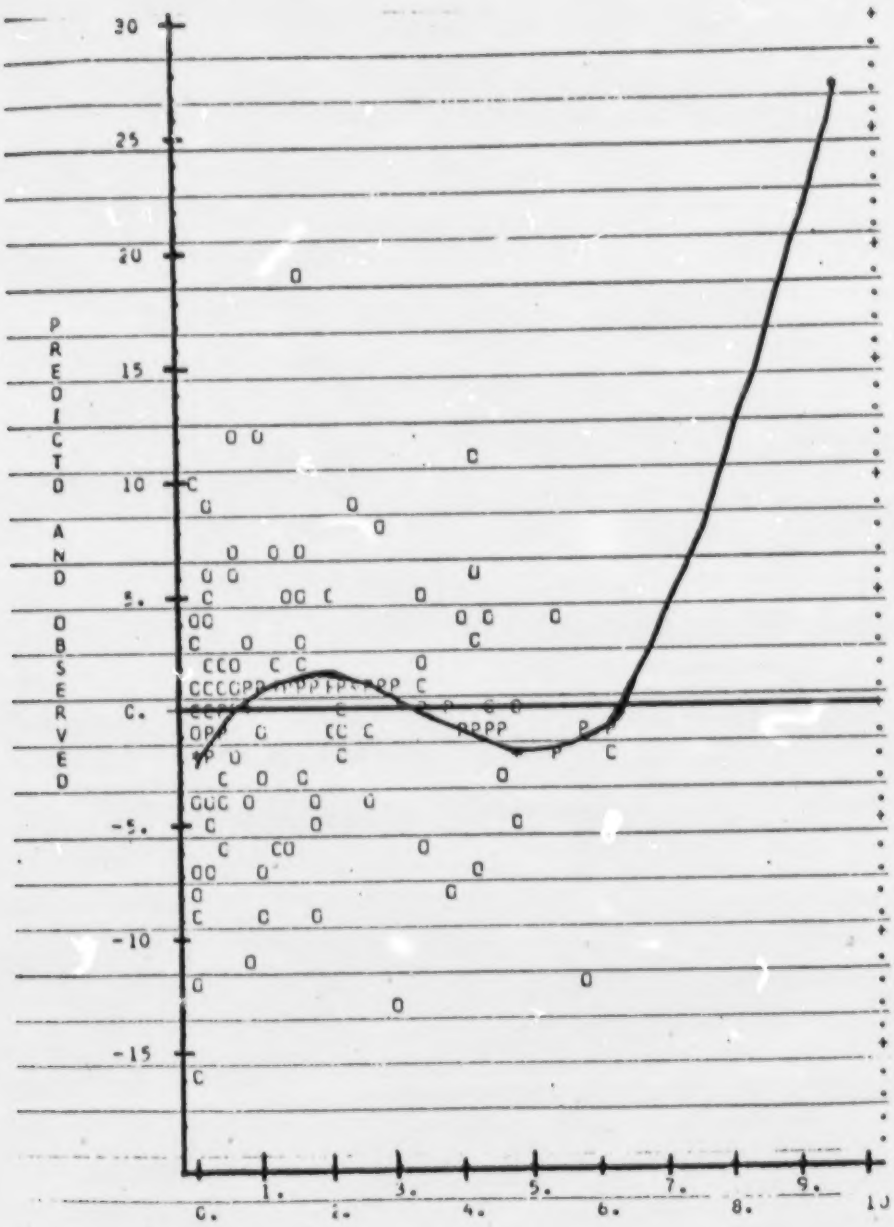

Figure 23. The process-product function for "child cooperation" (M/467a)--as related with mathematics achievement.

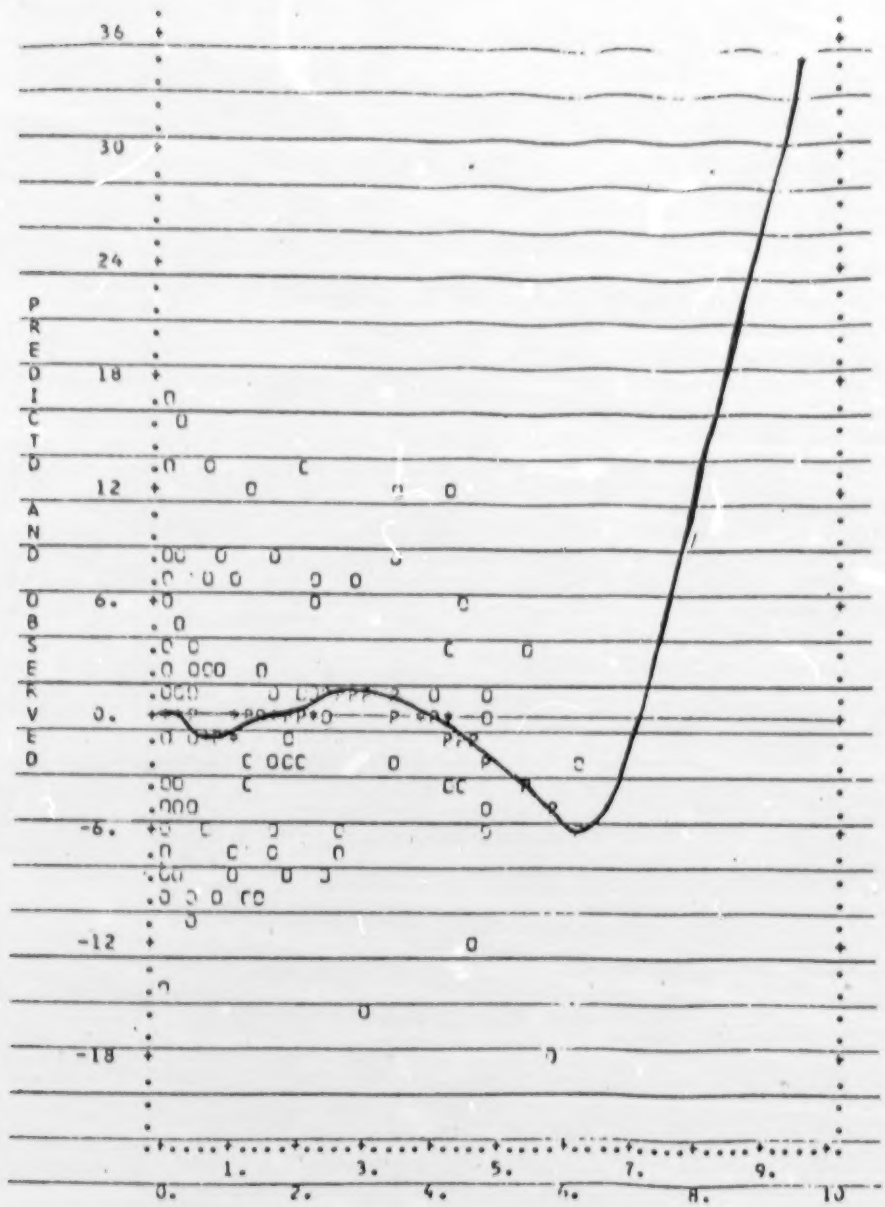

Figure 24. The process-product function for "child cooperation" (R/467a)--as related with mathematics achievement.

Child cooperation (vars. 467a, 598c) has a function not too unlike that of child self-esteem, with reading achievement; that is the highest levels of cooperation are associated with the greatest growth in achievement (see Figures 23 and 24). However, since the upward turn is due to a single outlier, such an interpretation must be treated with great caution, and indeed without this case the function might well approximate an inverted U shape.

Child attentiveness (var. 595c) is cubicly related to mathematics achievement and has a quadratic inverted partial U-shaped relationship with reading achievement. An examination of Figure 25, which represents the relationship between child attentiveness and mathematics achievement, reveals that this function is not unlike that for child "self-esteem" in respect to reading achievement. Figure 26 shows that reading achievement was maximal for classes having moderate amounts of child attention and that extremes of attentiveness were associated with decreasing amounts of student achievement. The fact that this variable is an aggregate of nonacademic and academic attention, as well as attention to machines, adds a measure of difficulty to the interpretation of this finding. Apparently, too little and clearly too much attentiveness, especially if the latter is nonacademically oriented, is nonfacilitative. The reason for the upward turn for mathematics achievement is less clear.

All variables listed in Table 11 have been dealt with in only cursory fashion in the literature; they are not the usual ones categorized as "qualities of environment." The fact that they all are composites clearly hinders efforts to compare these results with those of others. Nevertheless, the curvilinear findings suggest that this is still another set of relationships in need of additional study and research.

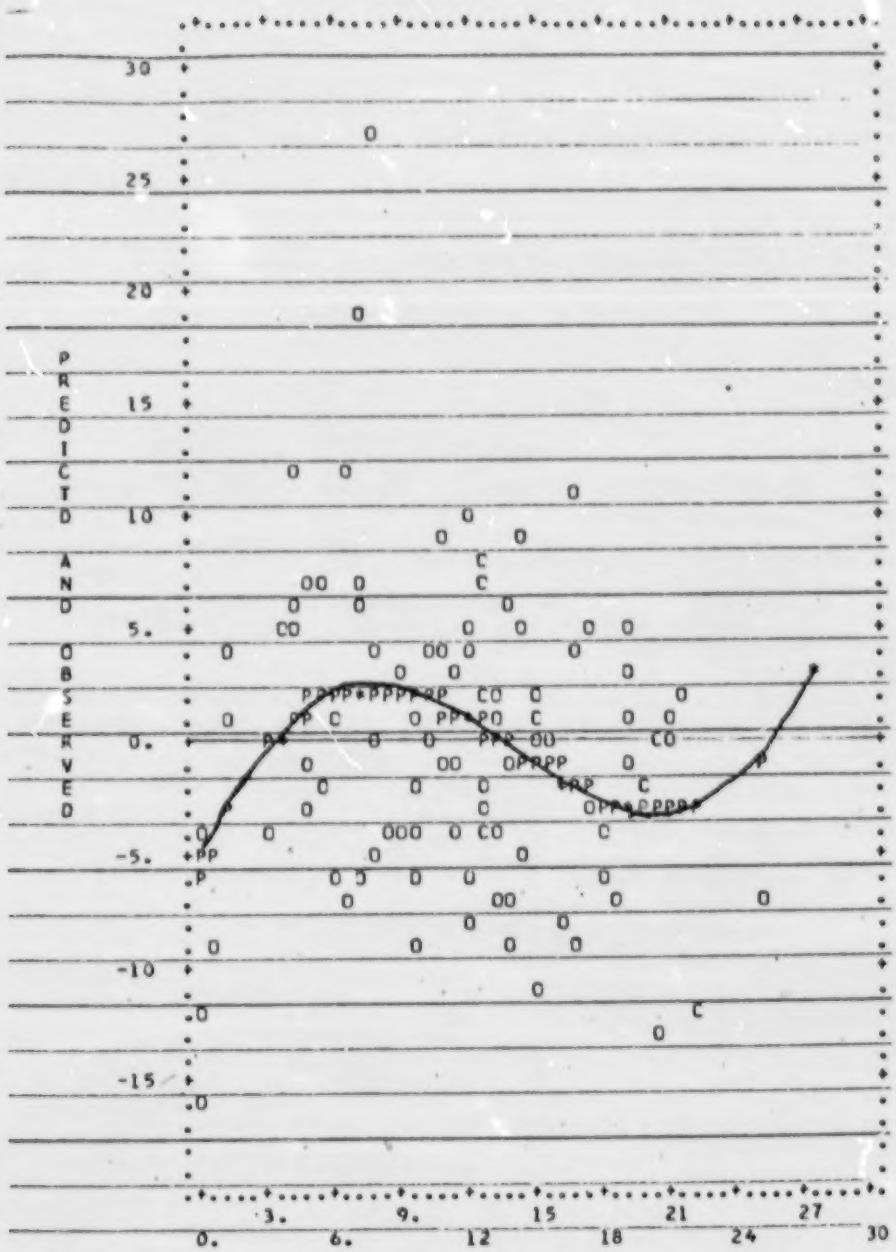

Figure 25. The process-product function for "child attentive" (M/595c)--as related with mathematics achievement.

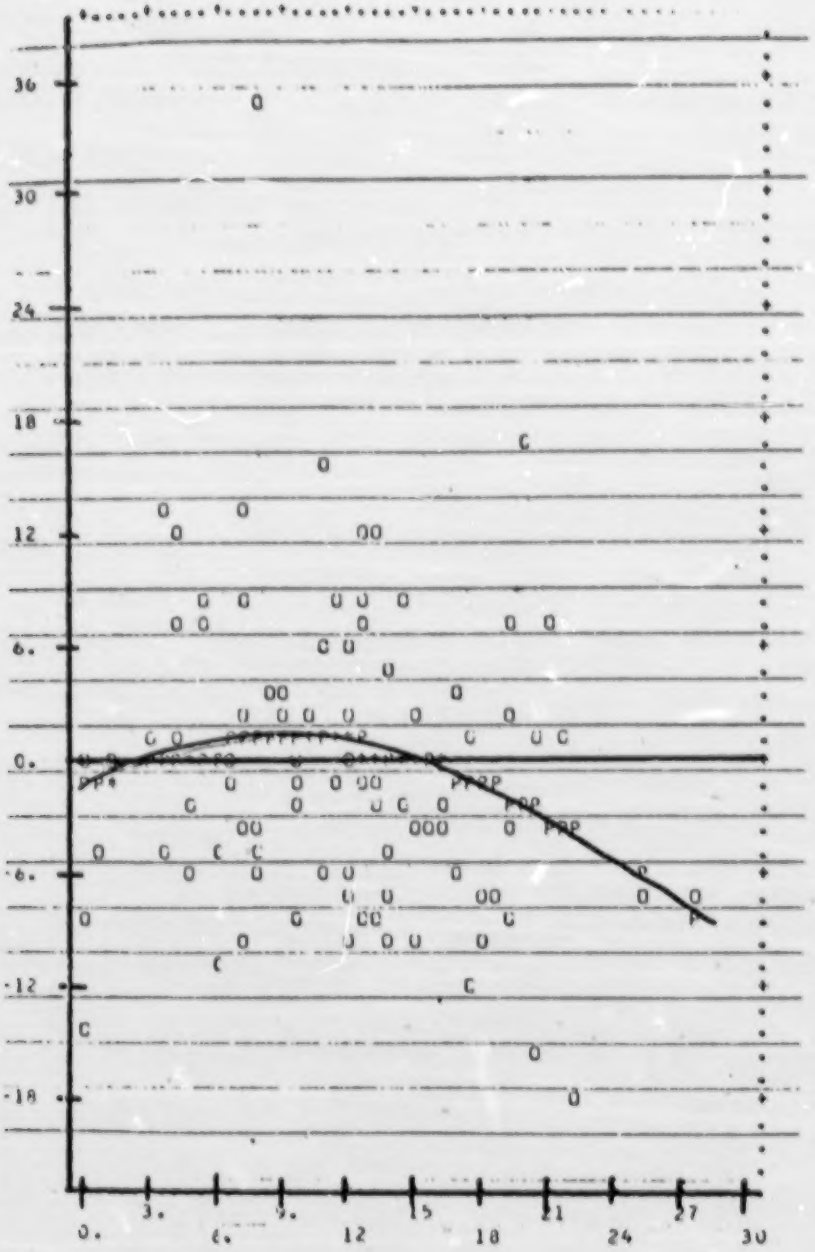

Figure 26. The process-product function for "child attentive" (R/595c)--as related with reading achievement.

VI. SUMMARY AND CONCLUSIONS

Data from 108 first grade classrooms included in the Stallings and Kaskowitz (1974) study were selectively reanalyzed using polynomial regression analysis. This secondary analysis was conducted in order to search for possible nonlinear relationships between classroom process variables and student achievement in reading and mathematics.

Of ninety-five relationships initially selected for reanalysis, thirty-two were found to be nonlinear. Three of these nonlinear relationships have an inverted U shape, four are best described as inverted partial Us, one has a negatively accelerating shape (i.e., ⌒), another has a negatively decelerating shape (i.e., ⌞), three have an upright U shape, another three are best described as upright partial Us, and the remaining functions were either cubic or quartic. Shapes referred to by Brophy and Evertson as"candy canes"were not found in this reanalysis. Some of the cubic and quartic functions could, if minor variation were disregarded, be treated either as inverted U or upright U shapes. All these nonlinear relationships are summarized in Table 12.

Inverted U-shaped functions were found to describe the relationship between mathematics achievement and the following two process variables: "percent of time spent on numbers, math, arithmetic (66), " and "total weight in math groupings (140)"; and between reading achievement and "variety of materials used (V10)." Inverted partial Us best describe the relationships between mathematics achievement and the following process variables: "adult academic commands/requests and direct questions to children (451a, 582c)" and "child's extended response to questions (585c)"; and between reading achievement and "child attentive (959c)." Brophy and Evertson indicate that inverted U-shaped curves:

Table 12

Summary of Nonlinear Functions

Degree	Shape	Variables	
		Mathematics	Reading
Quadratic	Inverted U (⌒)	66(1)**, 140(2)	V10(8)
	Inverted Partial U (⌒⌒)	451a(5), 582c(5), 585c(7)	595c(11)
	Positively Decelerating (⌒) Negatively Accelerating (⌒)		24(9)
	Negatively Decelerating (⌣) Positively Accelerating (⌣)		165(2)*
	Upright Partial U (⌣ ⌣)	V4(3)	V4(3), 453a(6)
	Upright U (⌣)	109(2), V2(2)	596c(10)
Cubic		V5+(2), 450a(7), 466a(11), 597c(11), 467a+(11), 595c(11)	15+(2), 466a(11), 597c(11), 467+(11), V1+(2)
Quartic		470a(10)	454a(7), 449a(10) 458a(10), 470a++(10) V7(2)

+: Minor variation of a basically inverted U shaped curve.

++: Minor variation of a basically U shaped curve.

*: Brophy and Evertson treated this type of curve as a decelerating curve even though in this reanalysis it had a cubic function.

**: Numerals in parentheses refer to tables as found in Section V.

> Depict a relationship in which some medium or optimal amount of the . . . process variable is associated with highest scores on the product criterion variable, with either too little or too much of the . . . process variable being less desirable than the medium optimal amount. (p. 22)

A negatively accelerating curve best describes the relationship found between reading achievement and a weighted composite called "child selection" (see Figure 18). A negatively accelerating curve (i.e., ⌒) generally indicates that low levels of the process variable being examined are marginally facilitative, but with increased levels the process variable becomes increasingly dysfunctional; the decline is initially a gradual one that becomes steeper with every increment in the process variable. A negatively decelerating curve may be used to describe relationships found between reading achievement and the variable "all children without adults in reading" (see Appendix, Figure D). A negatively decelerating curve (i.e., ⌣) generally indicates that low levels of the process variable being examined are marginally facilitative, but with increased levels the process variable quickly becomes dysfunctional, until a point is reached where there is a near zero rate of decline. However, in this reanalysis the latter-mentioned variable, that is, "all children without adults in reading (165)," is best described as an L-shaped curve. Such a function indicates that there is essentially a zero correlation between the two variables for most levels on the process variable, usually with some exception. In this instance, the shape was due to data from one extreme class.

Upright U-shaped curves were found to describe the relationship

between mathematics achievement and the following two variables: "one child with any adult (109)" and "classroom groupings: percent of adult-individual child interaction time (V2)." The same upright U shape describes the relationship between reading achievement and "adult feedback to children for behavior (596c)." Upright partial U curves were found between mathematics and reading achievement and the "percent of time a child was without adults (V4)," and between reading achievement and "adult response to child's question with a question (453a)." Upright U-shaped curves indicate that either low or high levels of the process variable tend to be associated with greater achievement gains. With only a few exceptions, relationships of this sort are hard to interpret. Brophy and Evertson feel that such curves "appear to be inherently uninterpretable . . . without other information about how a variable might be interacting with other variables" (p. 25). Since such relationships usually appear when the process variable is multidimensional (as in cases of aggregated variables) and/or when in interactions with context or other variables (Brophy & Evertson, 1976), such cases suggest the need for further study and analyses.

Cubic or quartic functions, which are even more difficult to interpret, were found for seven of the process variables as related to mathematics achievement. Ten process variables have a cubic or quartic relationship with reading achievement. Five of these functions were basically minor variations of inverted U-shaped functions, and one is basically an upright U-shaped function. Again, the multidimensionality

of the process variables and/or their interaction with other variables quite possibly are responsible for the nature of these functions. Further analyses and studies are needed to understand the root causes of these functions for these particular variables.

The findings of this secondary analysis effort show that in some instances, similar curves were obtained for the same variable across content areas (i.e., reading and mathematics) and/or across adult-focused and child-focused data. This suggests that the results are consistent and have meaning, although that meaning may not always be readily apparent. On the whole, quadratic functions are more or less easy to interpret, that is, given a straightforward process variable and not a composite. In general, most of the nonlinear quadratic relationships found through the present reanalysis, especially those described as inverted Us, inverted partial Us, and/or accelerating and decelerating curves, seem generally to be interpretable and, therefore, may be said to provide more worthwhile information than linear relationships alone.

Several cautionary remarks seem due at this point. First, Cronbach (1976) has cautioned against instigating a blind search for nonlinear relationships: "Nonlinearities may reasonably be explored, but unless there is a rationale for predicting nonlinearity, little credence can be given a nonlinear relationship the first time it turns up" (p. 3.11). In response to Cronbach's remarks, it is to be noted that the variables used in this reanalysis were selected on the basis of prior research findings and other theoretical considerations; it was not a random process.

Second, as mentioned in the methodology section, class mean reading and math scores were residualized on class mean WRAT scores because of existing conditions. It remains to be shown whether or not similar curves will obtain if the achievement test scores are residualized at the student level.

Third, statements made in this paper regarding "optimal" levels of classroom practice were not intended to be applied indiscriminantly; they are generalizable only to low-SES first grade children similar to the children studied by Stallings and Kaskowitz. In addition, these secondary reanalysis findings should be treated as being tentative and in need of confirmation.

Fourth, several of the reported nonlinear relationships are almost certainly caused by outliers. Without these outliers the functions would differ considerably. Some functions might even prove to be linear, (others quadratic), forcing conclusions drawn here to be substantially modified. An extremely conservative approach to this analysis might have been to drop all outliers. This alternative was not elected, and outlier data was treated as if they represented real effects. Soar and Soar (1976) have suggested that "perhaps researchers have been protected by teachers who have . . . not produced extreme amounts of the behaviors under study (p. 265). Perhaps some of the teachers in the Stallings and Kaskowitz study were not as protective of researchers as is usual of their colleagues.

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APPENDIX:

PROCESS-PRODUCT FUNCTIONS

NOT INCLUDED IN SECTION V

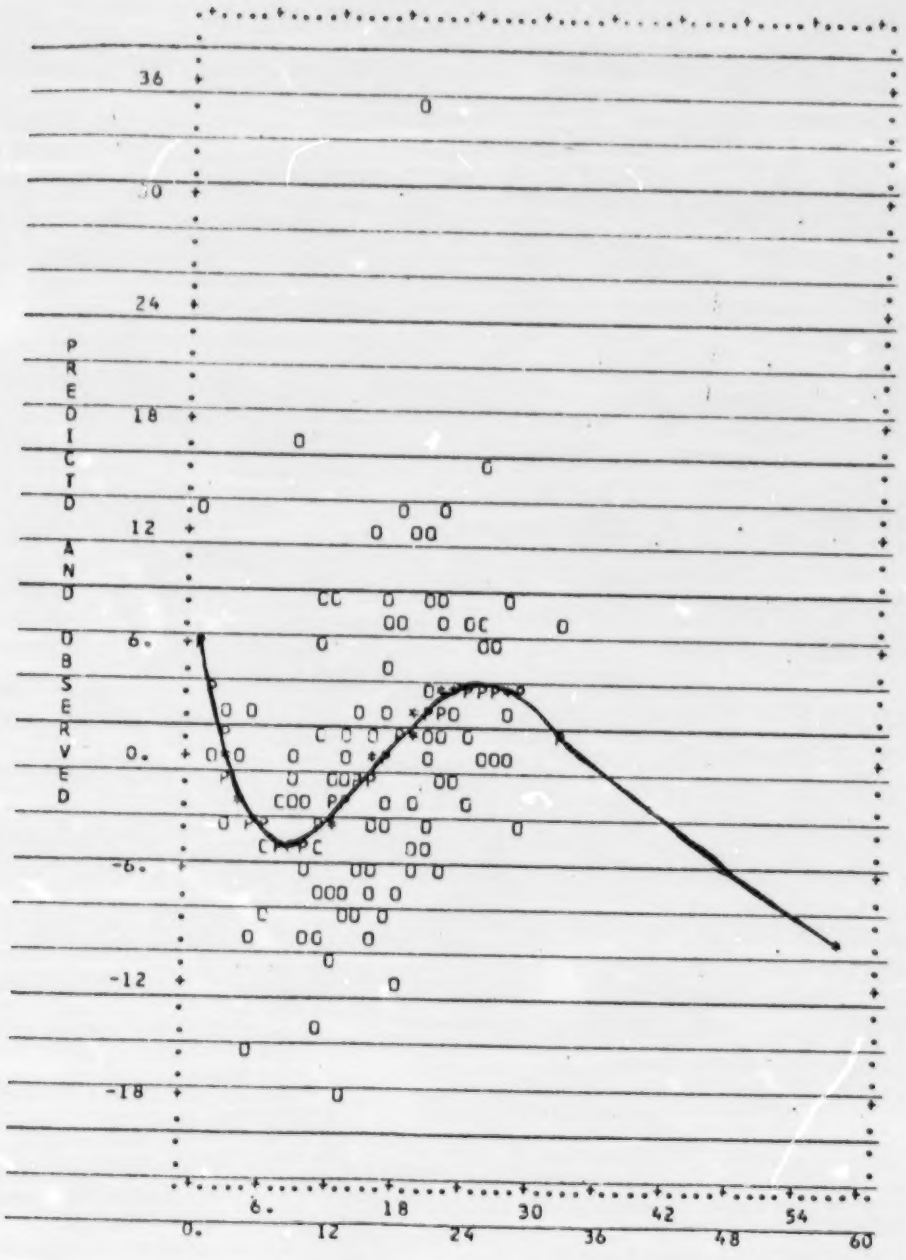

Figure A. The process-product function for "percent of "child time" spent on numbers, math, arithmetic" (R/66)--as related with reading achievement.

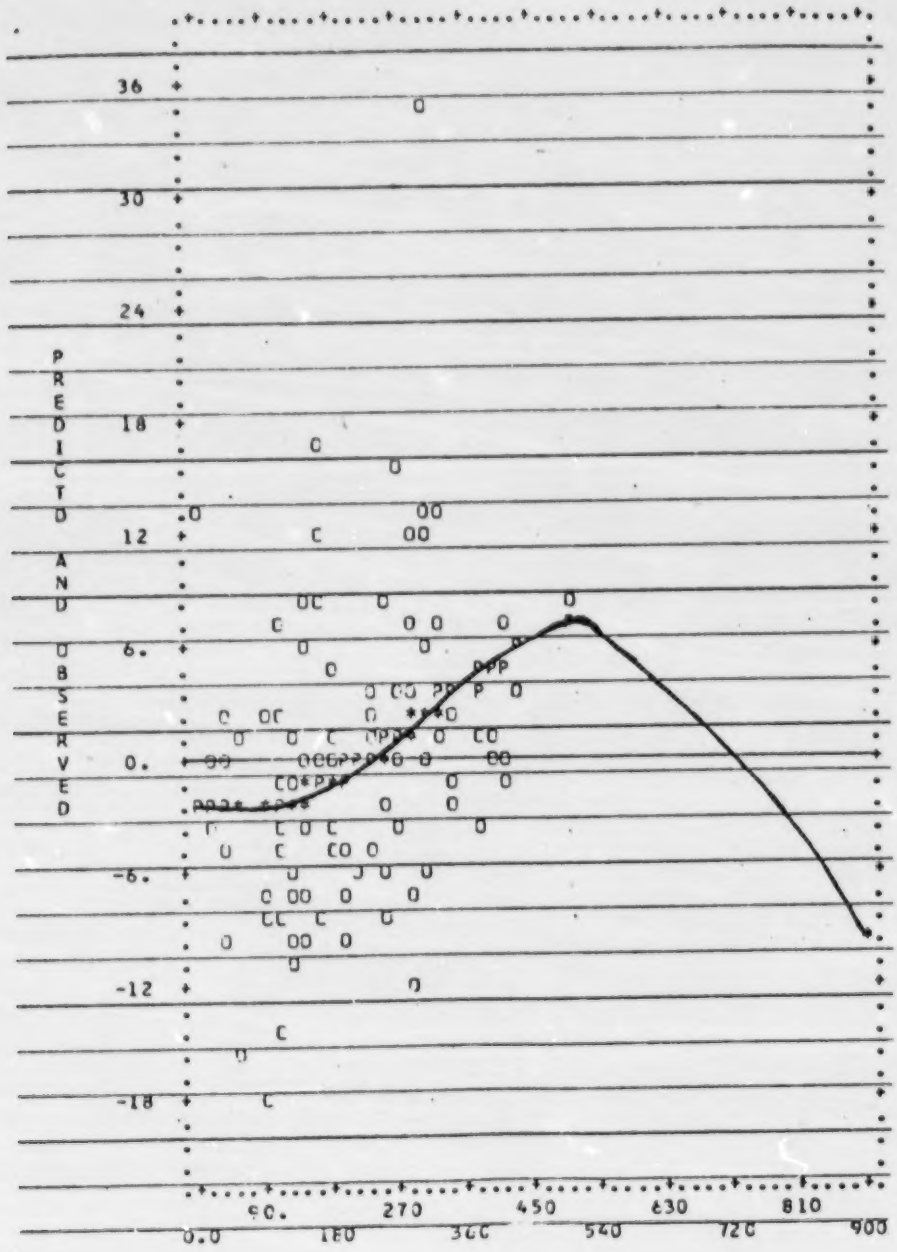

Figure B. The process-product function for "total weight in math groupings" (R/140).

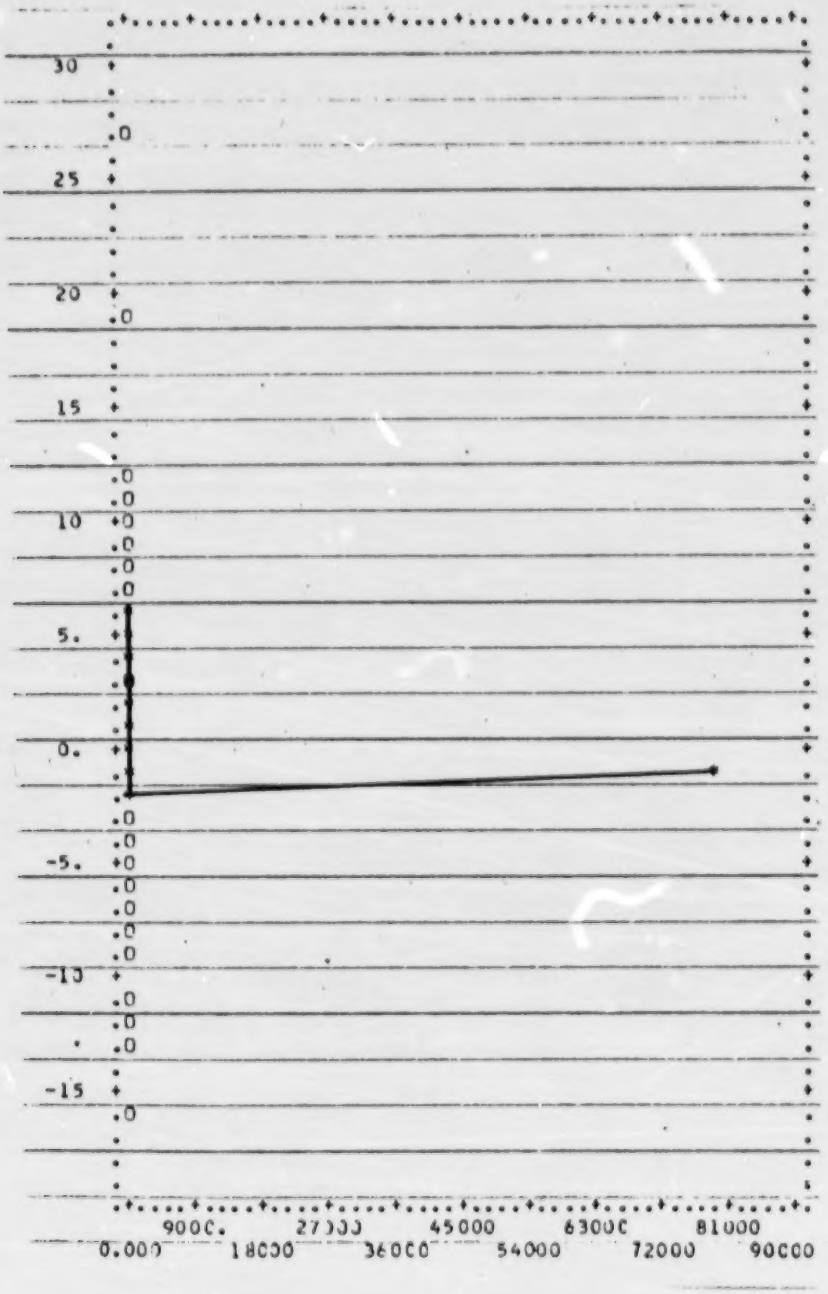

Figure C. The process-product function for "all children without adults in reading" (M/165).

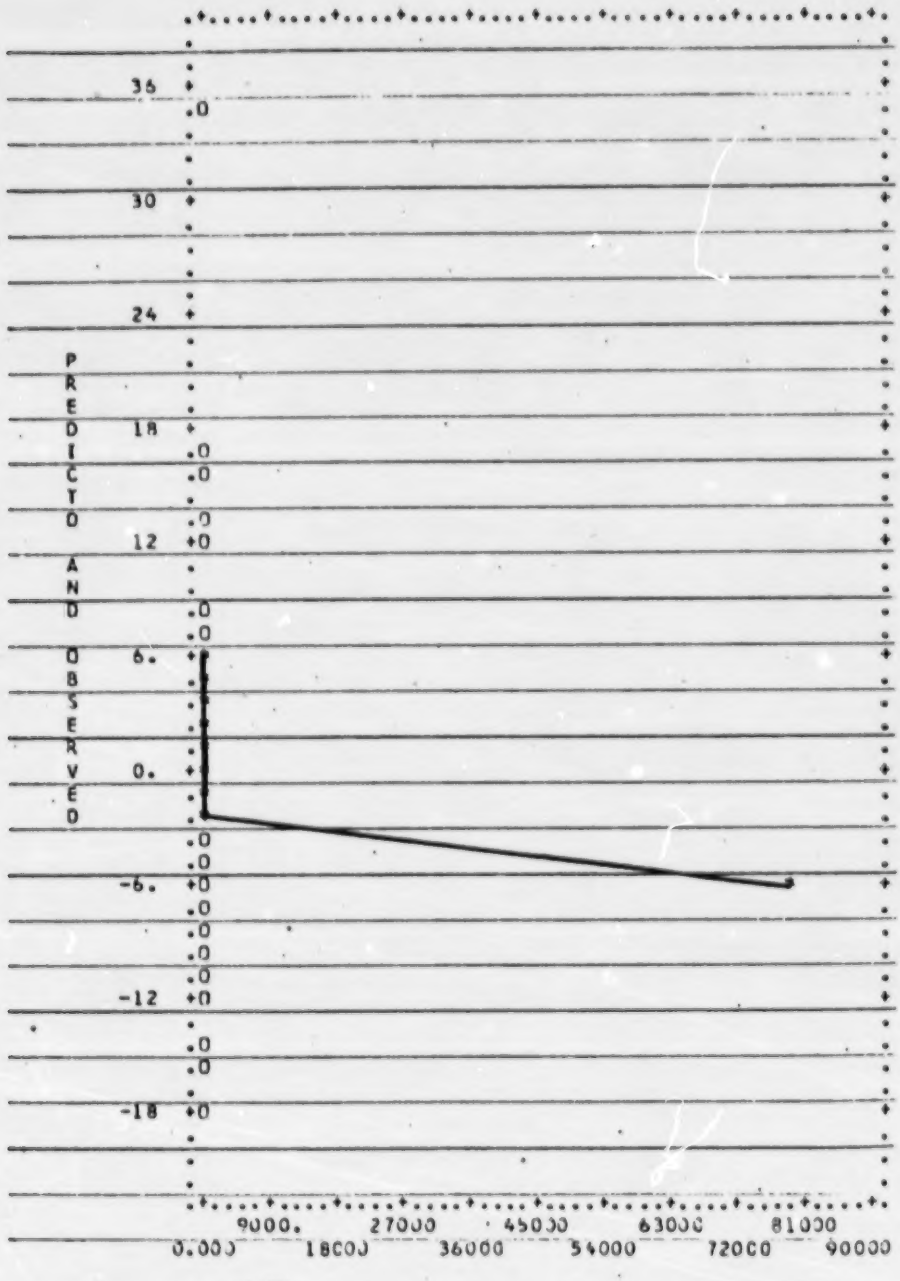

Figure D. The process-product function for " all children without adults in reading" (R/165).

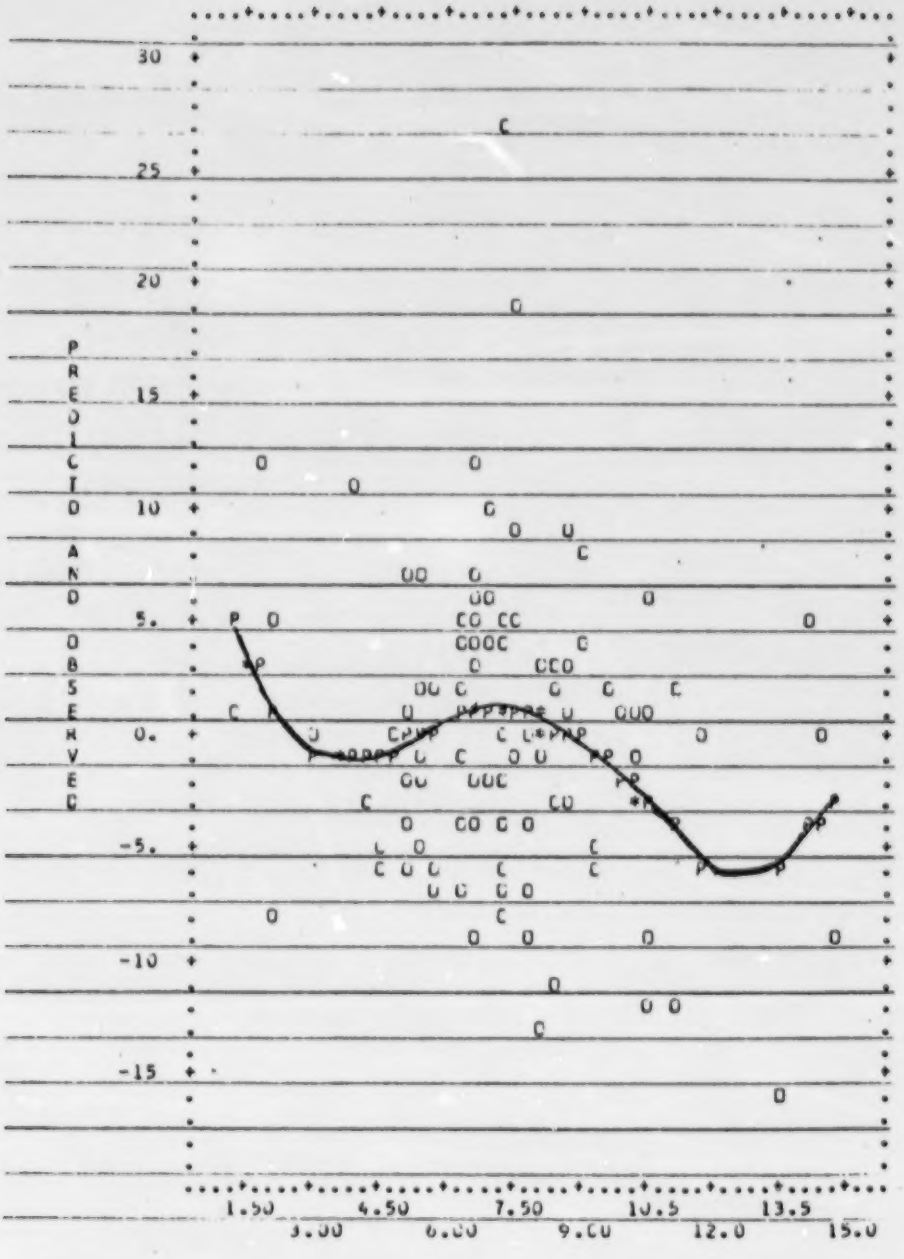

Figure E. The process-product function for "reading groupings: percent of teacher-individual child interaction time" (M/V7).

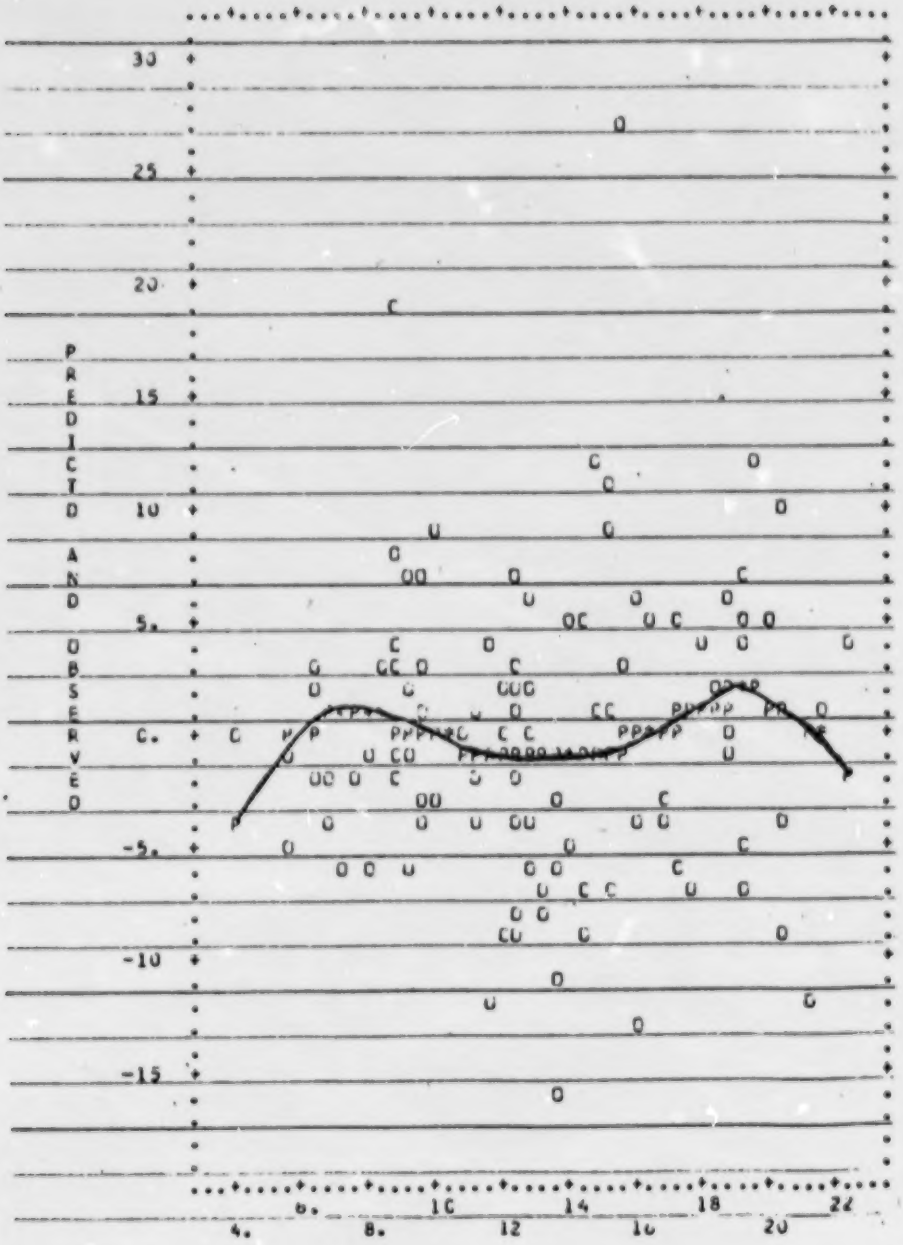

Figure F. The process-product function for "reading groupings: percent of child-any adult interaction time" (M/V8).

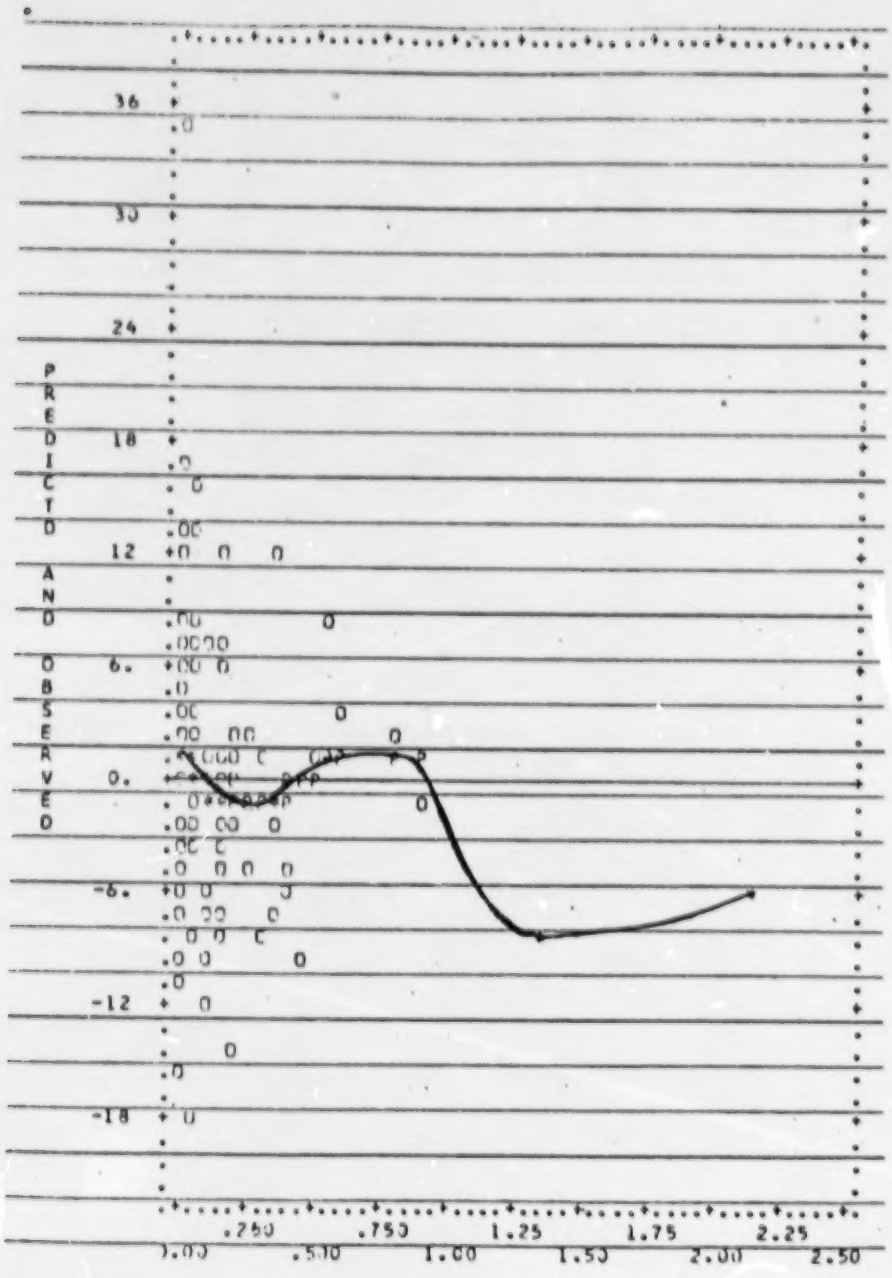

Figure G. The process-product function for "all adult negative corrective feedback" (R/458a).

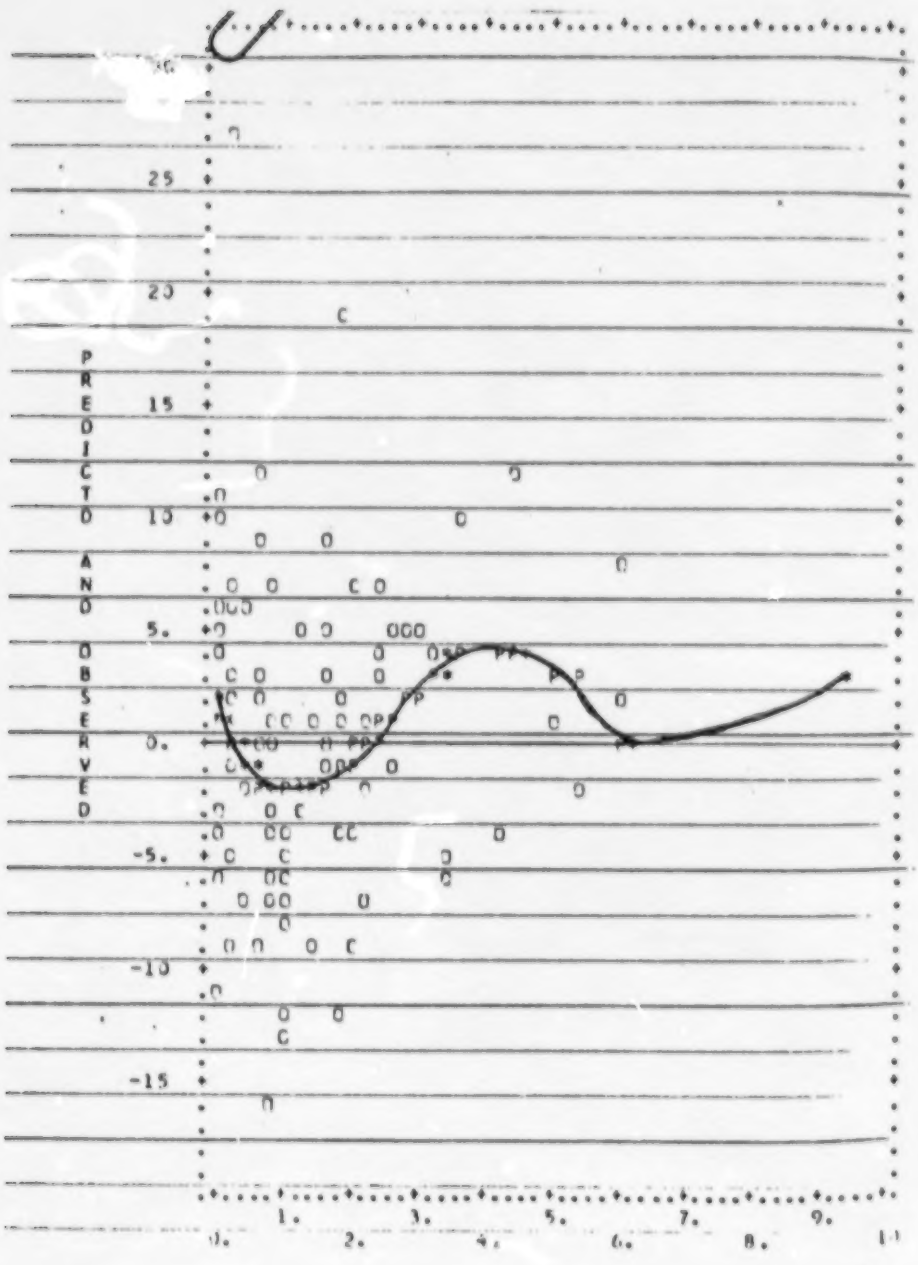

Figure H. The process-product function for "all adult neutral corrective feedback" (M/470a).

A-8

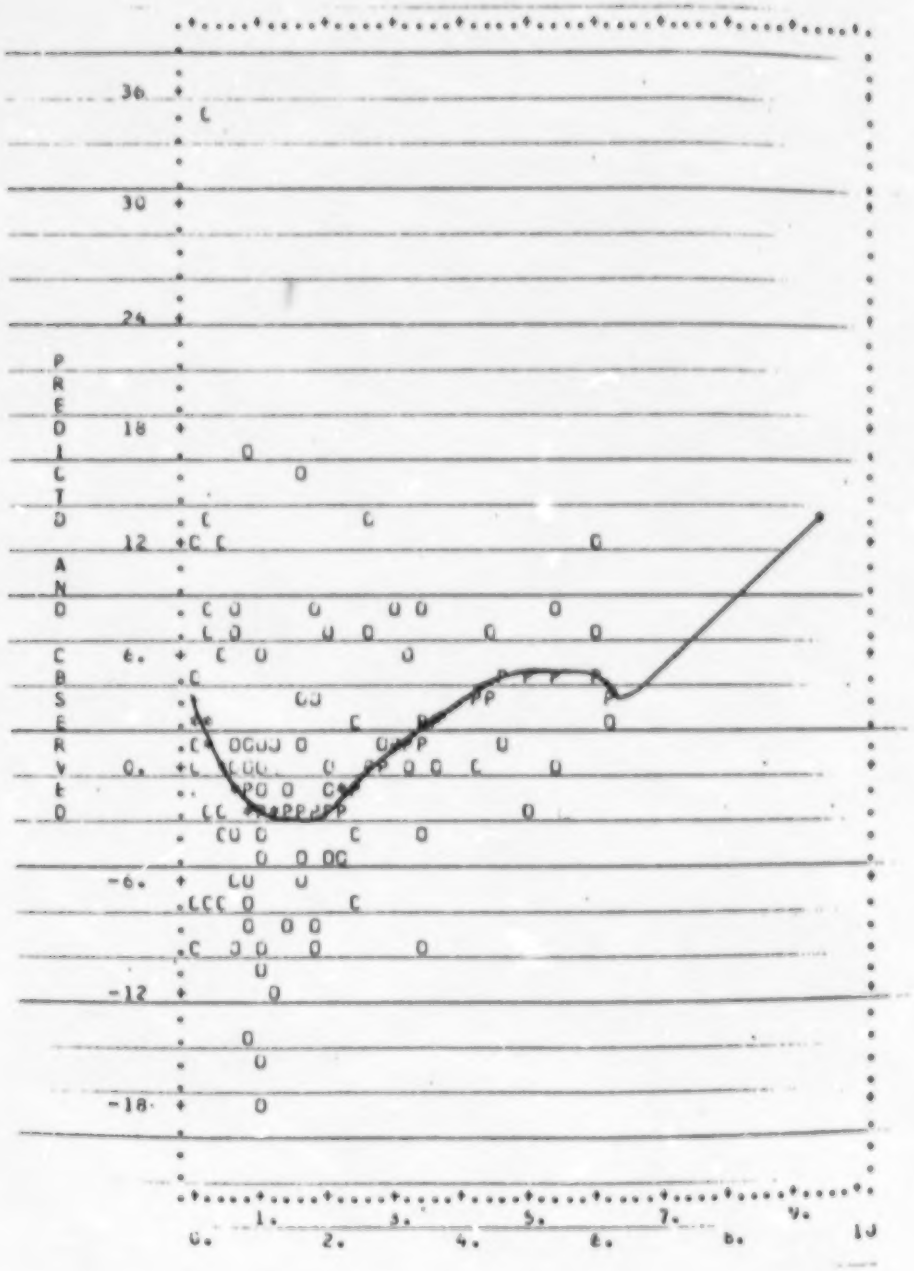

Figure I. The process-product function for "all adult neutral corrective feedback" (R/470a).

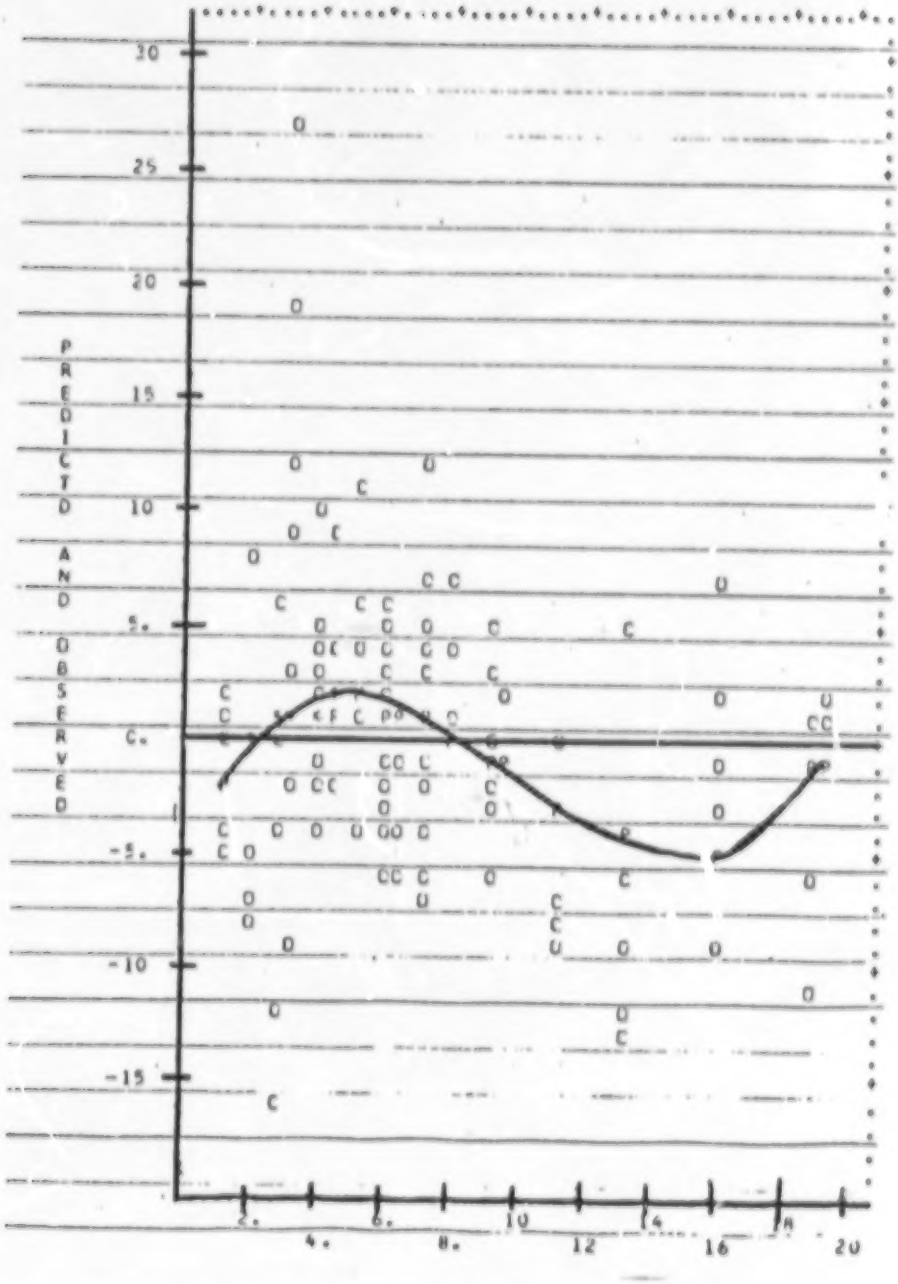

Figure J. The process-product function for "child self-esteem" (M/466a).

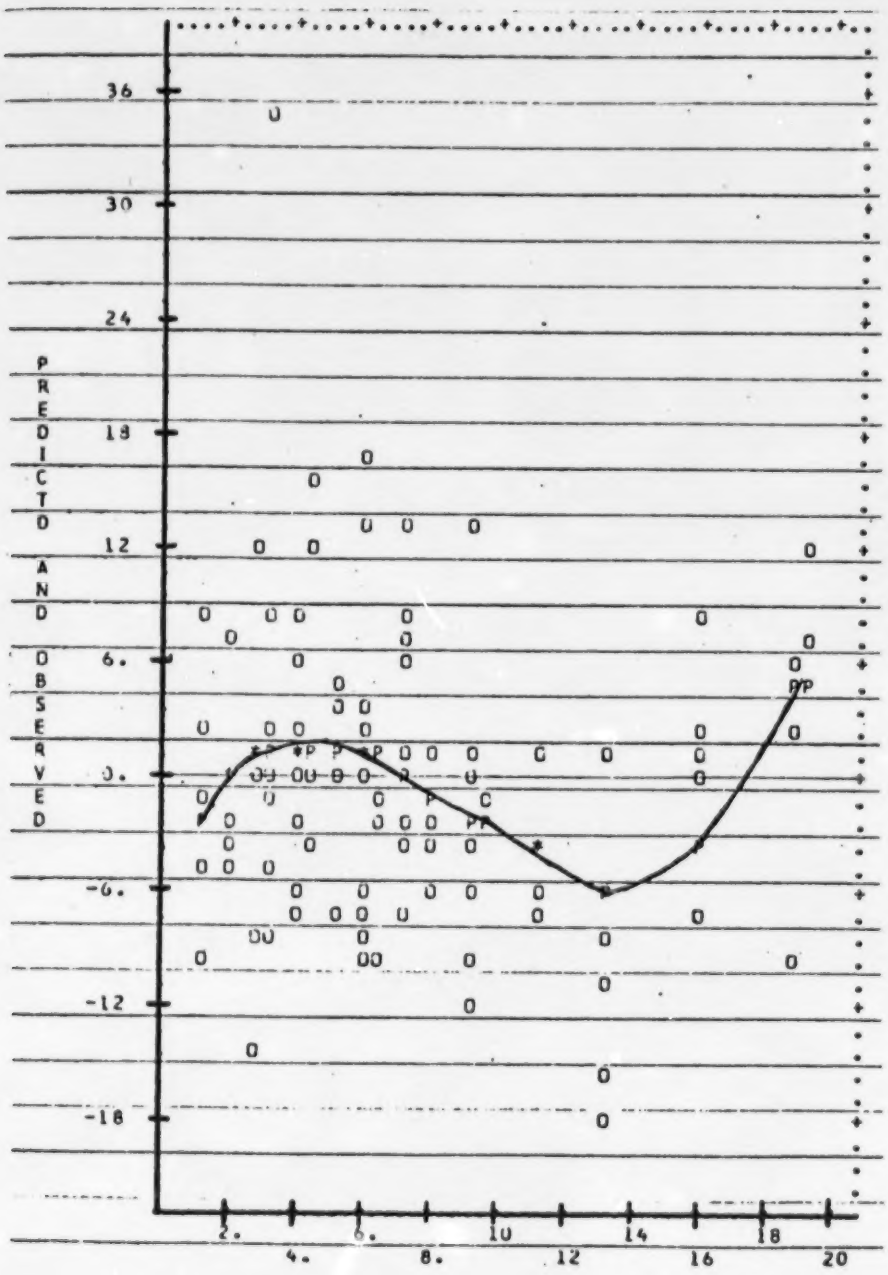

Figure K. The process-product function for "child self-esteem" (R/466a).